

Reconditioning

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In this chapter, we'll concentrate on bringing old parts back to like-new condition. We'll begin with general information that's applicable to the entire reconditioning process and then address the reconditioning of each specific component. Because the reconditioning of some components must occur in a certain sequence, the text will reflect that.

General Information Cleaning

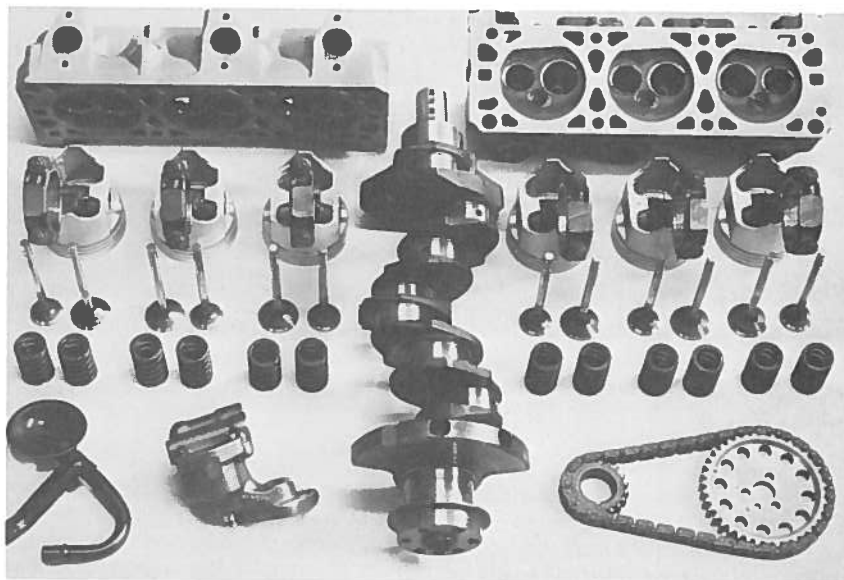
Of all the different operations involved in rebuilding an engine, the proper cleaning of components ranks among the most important.

Most engine components have machined surfaces that are actually quite delicate. Dirt and grime can destroy their surface finishes, causing premature failure. Therefore, you must make sure the parts are perfectly clean. Furthermore, cracks, gouges, and other imperfections that could be the cause of a particular problem are easier to detect when the parts are clean. You are also less likely to drop clean parts as they won't be slippery due to oil and dirt deposits.

In the course of cleaning the various engine components, you may need to use certain types of equipment, solvents, and chemicals that could cause bodily harm if not used correctly and cautiously. Wear safety glasses and rubber gloves as protection against unnecessary and potentially harmful exposure to these products, and be sure to read and follow all directions.

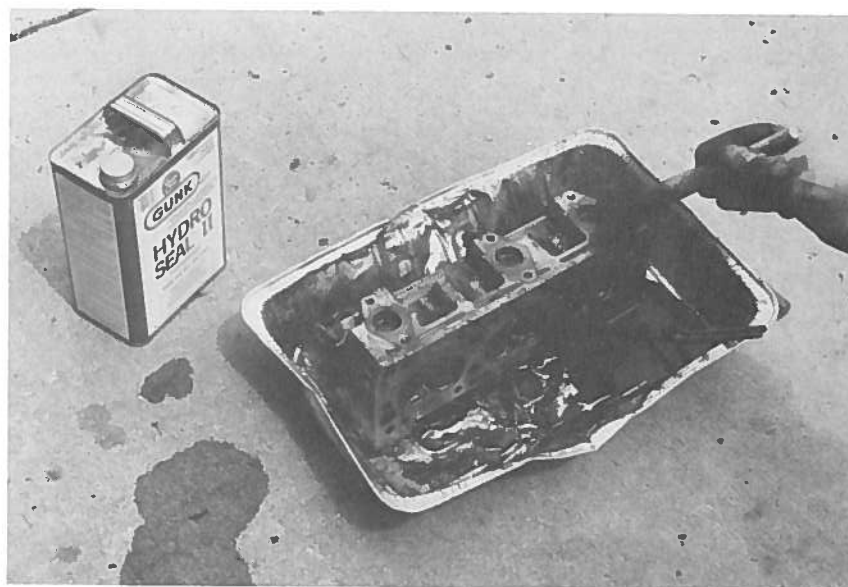
After cleaning the various parts, lay them on clean newspaper to air dry. Newspaper is even better than clean rags as it doesn't contain lint like *all* rags do (*clean* ones too), and the engine easily tolerates any particles that the parts do pick up from the paper.

Deposits on bolt threads can be removed with a wire brush, a rotary wire brush chucked into a drill motor, or with dies. The first two methods work well in most instances. Dies can



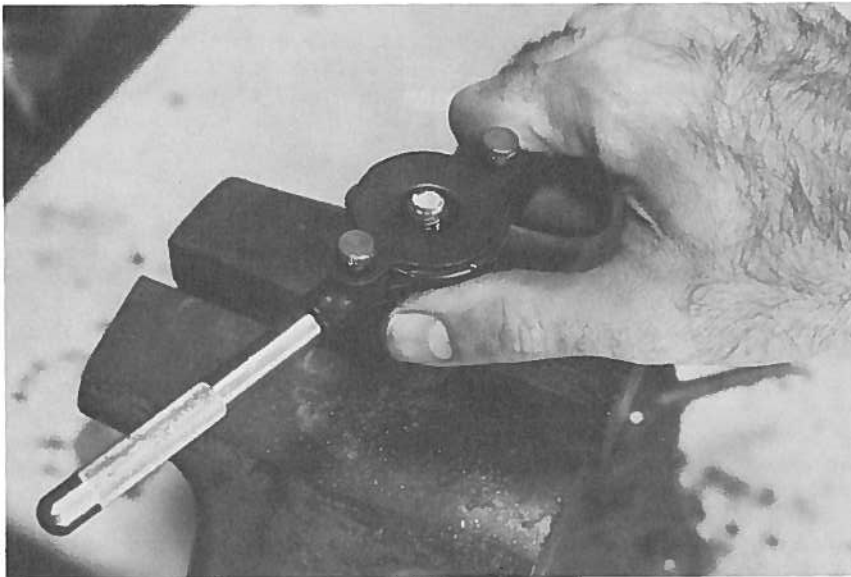
Although they're made of various alloyed metals and can withstand a considerable amount of abuse and neglect, engine components are actually quite

delicate. Consequently, they must be thoroughly cleaned and properly handled and assembled to give good service.



All parts should be thoroughly cleaned so that they can be properly inspected and reconditioned if necessary. To remove any remaining gasket material and carbon on aluminum components,

such as this head, soak them with a strong solvent such as Gunk's Hydro-Seal II. Scrape any residual debris away with a nylon scraper or an old toothbrush.



Dies are great for cleaning old sealer and crud out of bolt threads. Use a tap

to clean bolt holes. Clean threads are essential to accurate torque readings.

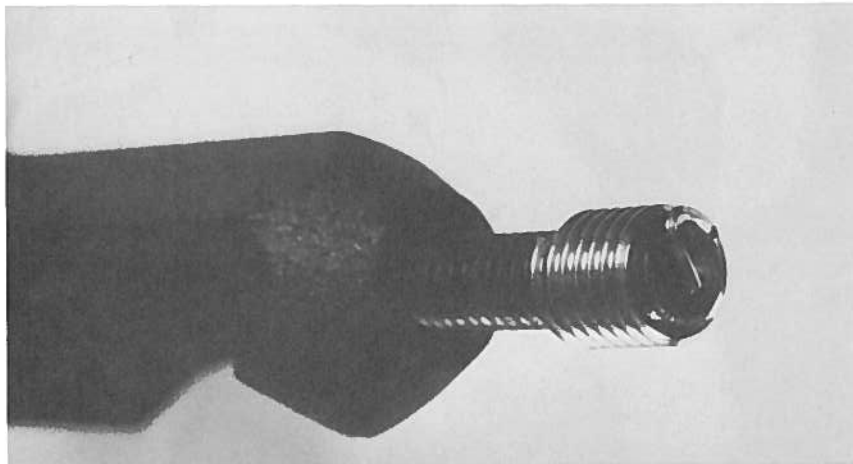
also be used to remove stubborn debris from between the threads. When cleaning bolts, be sure to remove any sealer from their shanks. And don't reuse bolts with rounded-off heads or stretched or damaged threads. Instead, replace them with bolts of at least the same strength and hardness.

Thread Repair

Repair stripped and/or worn threads with Heli-Coil thread repair inserts, which are available sepa-

ately or in kit form from most auto parts stores. Each kit typically contains inserts, an installation tool, a tap, a drilling guide, and instructions.

To install the insert, drill out the old threads, using the drill recommended in the drilling guide, then tap the threads, using the tap provided in the kit. If you're tapping into steel or cast-iron, you can use engine oil to lubricate the tap, but not if you're tapping aluminum since it will cause the tap to seize in the hole. Instead, use an anti-seize compound, such as



A thread repair kit, such as this one from Heli-Coil, can restore the threads in a component you thought was destined for the scrap bin. Make sure the insert tang fits against the step on the

installation tool. Screw the insert into the hole and break off the tang. The result is a threaded hole that's as good as new.

moly-lube or motorcycle chain lube with moly.

When the threads are cut, screw the insert onto the tool so that the tab of the insert rests against the flat on the tool. Next, position the tool into the repair hole and thread in the insert. When the insert is just below the top of the hole, unscrew the tool from the insert. Finish the job by breaking the tang off the insert with a pair of needle nose pliers or a screwdriver.

The insert requires nothing to keep it in position. Since its diameter is larger than the hole it's screwed into, it expands when in the hole. This outward tension holds the insert in place.

However, when you're repairing threads, remember that the hole you drill for the insert must be at a 90deg angle to the surrounding surface. This is especially critical if you're repairing the threads that accept the main bearing or cylinder head bolts, because if the hole is cocked, the bolts will bind within the bearing cap or cylinder head. This will lead to inaccurate bolt torque readings and possible disaster.

Crack Detection

Surface cracks can be detected in one of four different ways: your unaided eye, a spray-type dye penetrant, a commercial inspection process (Magnaflux for ferrous metals or Zy-glo for aluminum), or pressure testing.

Regardless of the method used, the area to be checked must be as clean as possible to provide the best opportunity for finding cracks. When 60deg V-6 blocks crack, it's typically at the lifter bores and the area between the head bolt holes and the two small pipe plugs in the lifter valley. Generally, these cracks are due to over-torquing of the head bolts or a weak casting.

Dye Penetrants

Spray-type dye penetrants are chemical formulations designed to penetrate and highlight cracks. Typically, three sprays are included in these kits: cleaner, penetrant, and developer.

To begin, spray the area you think may be cracked with a heavy, wet coating of the cleaner. After the area has soaked for about 30sec, wipe the cleaner off. If the area is still dirty, clean it again until all signs of dirt, oil, and grease have disappeared. Let

the area dry thoroughly before applying the penetrant. Now spray the penetrant on the area and allow it to soak in for 5min or so. Be sure to remove any excess penetrant with a rag dampened with the cleaning solvent, or you may "see" a crack that really isn't there.

To highlight cracks and pores, spray the area with developer. Any

faults will be outlined in the color of the developer. If this method doesn't reveal a crack that you think is there, you can have the area checked using the magnetic particle or Zyglol inspection processes.

Magnetic Particle and Zyglol Inspection

Magnetic particle inspection, of-

ten referred to as Magnaflux, is a process that works on the principle that a crack or defect in a part causes a break in its magnetic field. To begin this type of non-destructive testing, the part is magnetized with a large magnet or electro-magnet. Next a fluid containing fine, magnetic powder is poured onto the part. Since the part is magnetized, the magnetic par-

The Ins and Outs of Bolts and Nuts

At first glance, bolts and nuts appear to be pretty simple devices. You screw a bolt into a nut and *voila!*, whatever's between them is held tightly. Fasteners are not that simple, however. In fact, engineers and lay people alike are finding something new about bolts and nuts everyday.

Every bolt and nut used on the GM 60deg V-6 is metric. Most metric bolts have a strength rating on the top of their heads, typically ranging from 8.8 to 11.9. The higher the number, the stronger the bolt.

If you were going to build an engine for racing, you'd buy the strongest yet lightest fasteners available. They would be made of the best alloys and might be further strengthened by heat-treating, shot peening, or polishing. However, what's required for racing is usually overkill for production engines. While they're extremely light, racing fasteners are much too expensive to use when you're in the business of manufacturing more than 1 million engines per year. Consequently, more common metals and alloys are used to help keep costs down. This also means that the fasteners must be larger than the optimum for the job they need to do.

Fastener Torque

Torque is the twisting force applied to a fastener and is the most important aspect of the fastening operation. When a fastener is correctly torqued, it stretches slightly, like a spring. This tension keeps the fastener from loosening. It also keeps the fastener from wearing out because it never feels any load. On the other hand, if a fastener is under- or over-torqued, it can move back and forth, and the result is fastener fatigue and failure.

For optimum clamping force, the surface under the bolt head or nut must be at a 90deg angle to the bolt or nut. And that goes for any washers or lock washers that are used between the fastener and part as well. Check that no debris remains at the bottom of

a bolt hole, as it can prevent proper torquing.

Another variable in the torquing game is lubricant. Torque values can vary as much as 50%, depending on whether a thread lubricant is used. Also, different types of lubricants require different torques. Chemical thread lockers act as a lubricant as well.

Chemical Thread Lockers

Chemical thread lockers can be thought of as an insurance policy for bolts, nuts, and studs. They help keep fasteners fastened when real world realities intrude.

Before you use any chemical thread locker, clean the threaded surfaces of both parts. Any debris, such as old sealer, thread locker, or oil, will prevent the new thread locker from doing its job. Don't use solvents such as gasoline or kerosene, because they will leave an oily residue. Instead, use a chlorinated solvent, such as brake cleaner.

When both male and female threads are clean and dry, apply thread locker following the manufacturer's instructions. Usually, this means one drop on each mating part. Any more than this usually isn't needed. After you've applied the thread locker, you really don't need to hurry to install that bolt, nut, or stud. That's because

chemical thread lockers are anaerobic—they cure and harden when there is no oxygen present. So, the thread locker isn't going to cure until you've installed the fastener.

When the fastener is installed, the thread locker turns into a plastic film that bonds to the surface irregularities of the mating parts and holds them tightly together. The film also acts as a sealer, filling the voids between the male and female threads.

The advantages of using a chemical thread locker include a specific level of lubricity which helps ensure reliable torque readings, protection against fluid leakage and thread corrosion, and the ability to withstand most solvents and chemicals. Chemical thread lockers, such as those offered by Loctite, come in different strengths, viscosities, and temperature resistance. For most instances, you'll need Loctite's Removable Threadlocker 242, a medium-strength blue compound.

If you elect to use fasteners other than those supplied by the factory, ask your fastener supplier for proper torque specifications. If a bolt is harder than the original, it won't stretch as much when it's torqued to the same specifications as the factory bolts. And since proper bolt stretch is what helps keep the clamping load imposed by a bolt, if the bolt isn't stretched far enough, it will loosen.



The strength rating of these bolts increases as we move from left to right. The bolt rated 8.8 is used in applications where extra strength isn't required. The bolt rated 9.6 is used to retain the intake manifold. The next bolt,

rated 10.6, is quite strong and is used to retain the flywheel to the crankshaft. The bolt rated 11.9 is extremely strong and helps keep the bearing caps in position on the block.



Spray-type dye penetrants can help you locate cracks in components. They can also save you some money when

compared to crack detection at a machine shop.

ticles are attracted to, and cling to, any cracks. To aid in detection, the part is viewed under a blacklight; the light causes the magnetic particles to glow, indicating the locations of the cracks and their lengths.

Zyglo inspection is a process similar to Magnafluxing for checking for cracks in nonferrous metals, such as aluminum.

Pressure Testing

If you suspect a crack in a block or head and it hasn't been revealed by any other means, you should have the part pressure tested. Pressure testing will reveal cracks that the other methods miss. To pressure test a block or head, the core and drain plugs are installed, then rubber-coated steel plates are bolted to the

component and an air hose is connected to one of the plates. Finally, the whole thing is submerged in water and air pressure is applied. Any cracks will send out a stream of air bubbles.

Repairing Cracks: Welding Cast-Iron and Aluminum

Cracks in cast-iron and aluminum can sometimes be repaired by welding, but the required equipment can be quite specialized and you won't find it at common welding shops.

Cast-iron parts must be preheated to a specific temperature before welding, and special welding rods are necessary.

Aluminum components can be welded with shielded arc welding equipment, such as heli-arc, MIG, or TIG. The inert gas used in these processes shields the weld from exposure to impurities in the air—impurities that can cause defects in the weld.

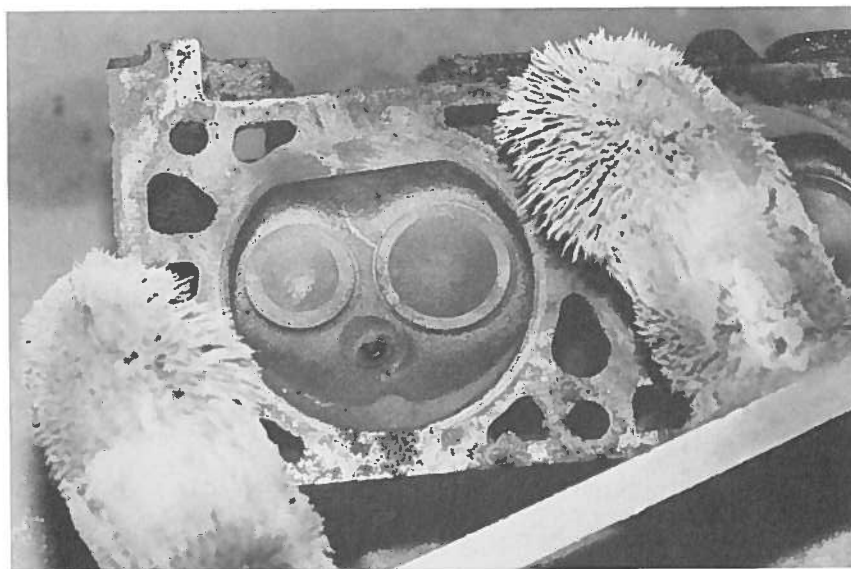
For either cast-iron or aluminum welding, a professional welder may be your best bet. Your local machine shop should be able to recommend a welder specializing in these types of repairs.

Epoxy-Based Adhesives

In some instances, two-part epoxy-based adhesives, such as JB Weld, can be used to repair cracks. This may sound a little far-fetched to some of you, but I know it works because I've used it on a number of engine components, including cracked blocks and cylinder heads. However, I would caution you about using this type of material where it's consistently exposed to temperatures over 250degF.

To begin your repair, you need to prevent the crack from spreading by drilling a 1/8in hole at the crack's migrating end. After drilling the hole, prepare the part for the adhesive by cleaning the crack and the surrounding area with a wax and grease remover, such as DuPont's Prep Sol. Alternately, you can use a chlorinated solvent such as brake cleaner. Then to increase the surface area for the material to adhere to, grind the crack into a small "V." Clean the area one more time with Prep Sol, let it dry, then mix and apply the material as per the label directions.

After you apply the material, lay the part down so that the crack is in a horizontal position. This will prevent the material from flowing out of the



Magnafluxing uses a special powder and magnetic force to find cracks in fer-

rous materials. The magnet used to impart the magnetic field is shown.

Using a Micrometer

Micrometers are precision measuring instruments. Properly used, they're the tools of choice when it comes to determining operating clearances between engine components because they can measure the thickness of an object in thousandths (0.001), or even ten-thousandths (0.0001) of an inch. Because of the need for extreme accuracy, micrometers have a range of only 1in. Consequently, they read 0–1in, 1–2in, 2–3in and so on.

Micrometer Anatomy

Basically speaking, a micrometer has six parts: the anvil, frame, spindle, lock, hub, and thimble.

To aid in visual identification when measuring, both the hub and thimble have lines on them. The hub has forty lines on it dividing the 1in range of the micrometer into forty equal parts. Consequently, every line on the hub is equal to 0.025in. Every fourth mark on the hub is larger than the others and is numbered. These larger lines are equal to 0.100in. The thimble is marked with twenty-five equally spaced lines, each of which equal 0.001in.

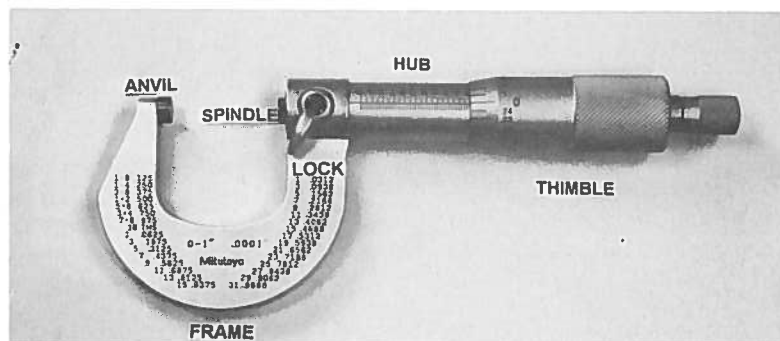
If you happen to have a micrometer that measures 0.0001in, eleven lines will run across the diameter of the hub. Each of these lines is equal to 0.0001in.

Measuring

To read a micrometer, simply add all the numbers together to calculate the measurement. For example, the accompanying picture shows a 2–3in micrometer. Consequently, the reading begins at 2.000in. Now look at the hub to see which number is closest to the thimble. In this case, it's four. Remember, these numbers are equivalent to 0.100in, so you would add 0.400in to your total. Now look to see how many short lines are between the number four and the thimble. Three lines are visible; since each of these lines equals 0.025in, add them ($3 \times 0.025 = 0.075$ in) to your total.

Now look at the numbers around the edge of the thimble to see which one is aligned with the line on the hub. In this case, it's nine. This number represents 0.001in, which is equal to 0.009in. So add 0.009in to your list and then total the numbers:
 $2.000 + 0.400 + 0.075 + 0.009 = 2.484$ in

The greatest factor that affects the accuracy of a micrometer is operator skill. You need to develop a "feel" for how tightly to turn the thimble for the most accurate results. It's the light touch that allows the spindle to gently contact the surface time-after-time that gives the best results. How you hold



Proper use of a micrometer will allow you to accurately measure engine components, which will help you judge

whether a component needs to be re-conditioned or replaced.

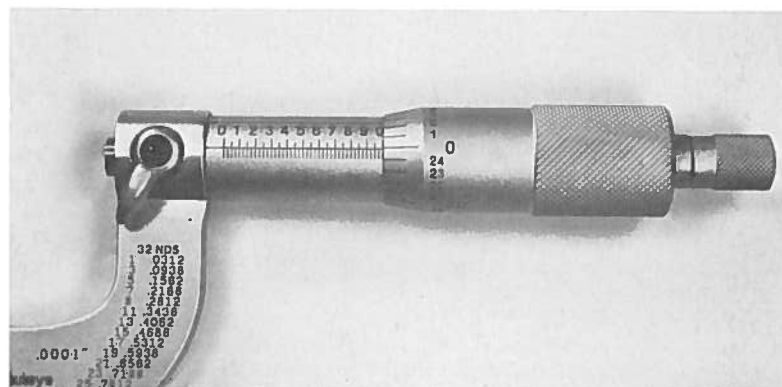
the micrometer has a direct bearing on the accuracy of your readings as well. The textbook way for holding a micrometer is with one or two fingers overlapping the frame while you rotate the thimble between your thumb and your first two fingers.

Using a Telescoping Gauge

A micrometer is often used in combination with a telescoping gauge.

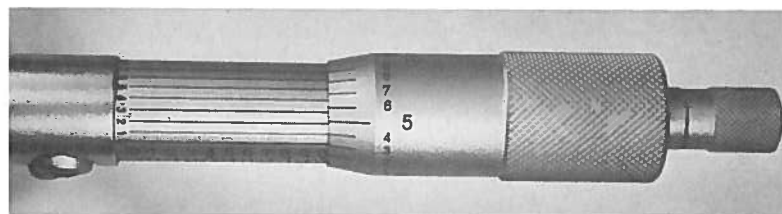
A telescoping gauge allows you to measure the inside diameter of a bore, like a rod or cylinder bore.

To use a telescoping gauge, place it in the bore you want to measure, then release the tensioner on the end of the gauge handle. This allows the gauge to expand to fit the bore. For the greatest accuracy, the gauge handle must be at a 90deg angle to the bore. When you're satisfied that the



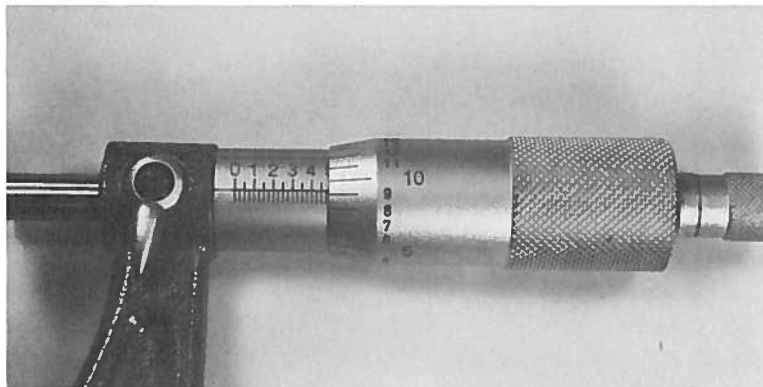
The horizontal numbers (on the hub) indicate 0.100in. Each mark below the horizontal line denotes 0.025in. The

vertical numbers (around the thimble) indicate 0.001in and run from 0 to 25.

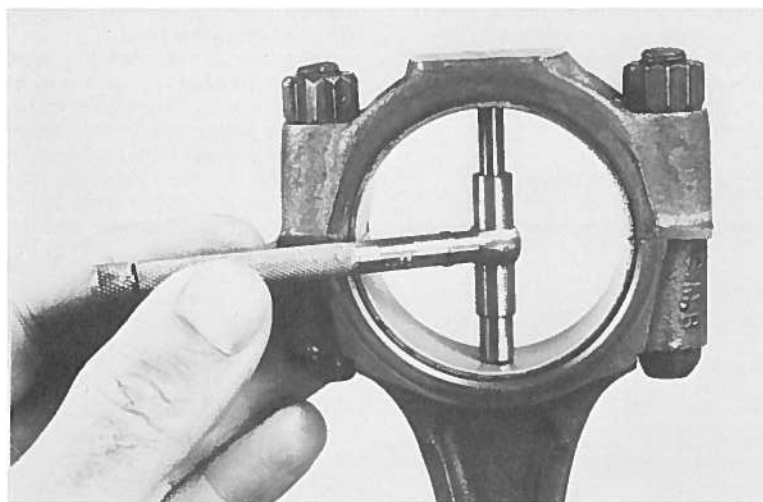


You can determine how many ten-thousandths (0.0001in) of an inch a part is by matching any line from the thimble with any line on the top of the hub. Whichever number that runs around the perimeter of the hub most

closely matches a line on the spindle indicates the number of ten-thousandths. In this case, the line for the number one most closely matches with a line on the thimble, so this is 0.0001in.



Reading a micrometer is as simple as adding numbers.



A telescoping gauge will allow you to check operating clearance between the crankshaft, block, and connecting rods.

gauge has expanded to its fullest, tighten the tensioner and remove the gauge.

Finally, measure the gauge with a micrometer. The difference between

the bore diameter and the shaft that fits inside of it indicates clearance. Check the bore size at least three times to achieve the most accurate results.

crack as the material sets up. Typically, these materials set up in an hour or two, depending upon ambient temperature, and are fully cured after 24hr. After curing, the material can be filed, ground, or machined as necessary.

Selecting Parts

As you proceed through the reconditioning process, you may find that several parts need to be replaced. Parts selection is based on a number

of things, including your budget, what parts are needed, how long you're going to keep the engine (and the vehicle that surrounds it), availability of parts in your area, the quality of the local auto parts stores, the pros and cons of buying parts through the mail, and the manufacturer's reputation.

Seeking quality replacement parts cannot be stressed enough. Since you're going through all the trouble of removing the engine, rebuilding it, and installing it, it only

makes sense for you to use quality parts. Off-brand parts offered at a discount are no bargain, and can cost you a lot more over the long run because of their lack of fit and durability.

No matter where you buy your parts, buy quality. Sealed Power, Federal Mogul, Fel-Pro, McCord, Glacier-Vandervell, TRW, ARP, Crane, Crower, and Isky—to name a few—all make quality parts on which you can depend. And don't forget about GM parts. Though they might cost a little more than some of the aftermarket parts, feedback from the field guarantees that they're continually updated—featuring improvements that some aftermarket parts manufacturers aren't able to incorporate into their products until months down the road.

Reconditioning the Cylinder Block

The cylinder block for all production 60deg V-6 engines is manufactured from cast-iron. In an unusual twist for GM V-type engines, the right-hand cylinder bank (rear bank on front-wheel-drive vehicles) houses the odd-numbered cylinders (1, 3, and 5), and the left-hand cylinder bank (front bank on front-wheel-drive vehicles) houses the even-numbered ones (2, 4, and 6). An easy way to remember this is that the first cylinder bank that comes closest to the timing chain houses the first (#1) cylinder.

Thread Chasing

Bolt torque readings are based on clean threads. To ensure this, clean all the threaded holes in the block with the requisite metric taps. After cleaning all the threaded holes, blow them out with compressed air. When the block is completely prepped, you can wash the sludge from the threads away.

Bearing Cap Fit

To maximize bearing and crankshaft life, the main bearing caps must fit tightly into the block. If a cap fits loosely, it will move around as the crankshaft rotates, causing considerable damage. If a main bearing cap on your block fits this description, you'll need to have the machine shop repair it. Machinists usually do this by trial fitting other main bearing caps until they find one that fits the block pretty snugly. Then they shave the mating surface of the cap to decrease its diameter. The job is finished by

torquing the cap into position and align honing the block.

Lifter Bores

To ensure that the lifter bores are free from varnish and other contaminants that would cause the lifter to hang up in the bore, use a brake cylinder hone to clean each bore. Run the hone through each bore (at low rpm) for about 5sec. Center the stones in the bore and be careful not to cycle the hone in and out of the bore more than 1/2in or so. This prevents the stones from popping out of the lifter bore, which can gouge it.

When you've finished honing, check your work with a used lifter that's had its body lubricated with oil. If the lifter slides in and out of the bore with only the force of its own weight, the bore is clean. If it doesn't, hone the cylinder a little more, then check it again. Don't hone the bore any more than necessary, as an over-size bore can cause a loss of oil pressure.

Checking Deck Flatness

For the cylinder head gasket to perform as it was designed to, the cylinder block's deck—that is, the surface of the block that mates with the heads—must be almost perfectly flat. During a "normal" rebuild, checking deck flatness is just part of the routine, but if the engine was overheated and/or the cylinder head gasket had blown, it is an essential check, as it may direct you to the source of the problem. To check deck flatness, you'll need a machinist's straight edge and a set of feeler gauges.

Prepare the deck by scraping away any debris. It must be absolutely clean to ensure accurate measurement. Lightly clean stubborn areas with a red Scotchbrite pad (available at auto paint stores and some hardware stores).

Since the longest expanse has the greatest potential for warpage, lay the narrow side of the straight edge across the center of the bores, running from the front of the block to the rear. While holding the straight edge lightly in this position, slide a 0.0015in feeler gauge between it and the deck on both sides of all three cylinders. If this gauge fits in at any point, insert the next-largest feeler gauge. Proceed in this fashion until the gauge no longer fits in. The largest gauge that did fit in represents the total warpage.



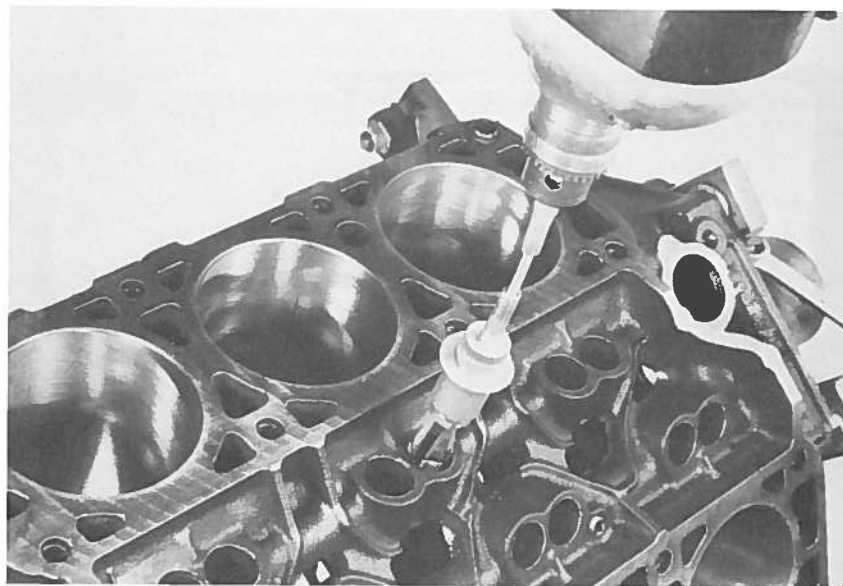
Epoxy-based adhesives, such as JB Weld, can be used to salvage a part that was destined for the scrap bin. The

Loctite brand is new to the game, but the company has a reputation for reliability.

If this figure is 0.003in or greater, the block will need to be decked to prevent a head gasket failure. If it's less than 0.003in, check the deck again, but hold the straight edge diagonally from corner to corner. Then hold the straight edge across the two remaining corners. Be sure to check both cylinder banks using this technique.

Trial Assembly

At this point, it would be wise to clean the main bearing saddles in the block (along with the main bearing caps), crankshaft, connecting rods, and main and connecting rod bearings (but don't clean new bearings) before you send anything to the machine shop. This will allow you to trial assemble these parts to check bearing



Use a brake cylinder hone to recondition the lifter bores. Don't push it in or

pull it out too far, because it can pop out of the bore, damaging it.

High-Performance Tip: Grinding

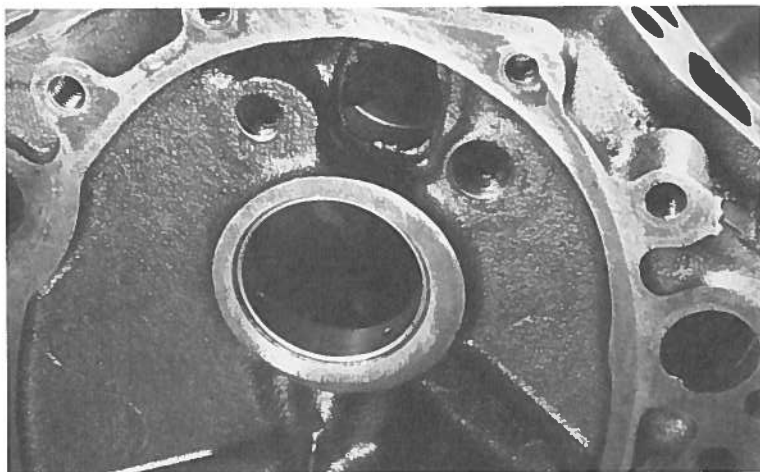
To reduce the chances of stress risers causing your block, heads, or crankshaft to crack, chamfer all sharp edges. This includes the main bearing webbing, bolt holes, timing chain cover, cylinders, and cylinder deck—literally every sharp edge.

Pay particular attention to the oil return passages in the center of the block, as they typically contain large amounts of flash from the casting process. If the flash is severe enough, it can restrict or even prevent oil from draining back into the oil pan, starving the engine of much-needed oil.

On cylinder heads, focus on the bolt holes, ports, coolant passages, and the perimeter of the heads. Also

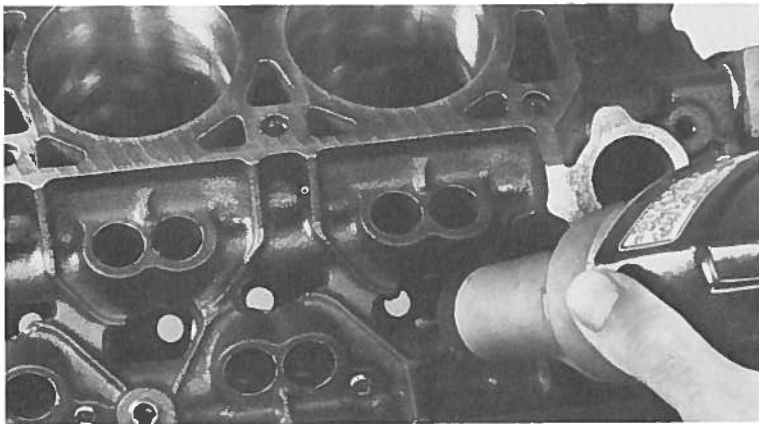
smooth the edges of the combustion chambers and the spark plug threads where they meet the chambers. Even a small fragment of metal hanging into the combustion chamber will turn red hot when the engine is running, igniting the air/fuel mixture and creating spark knock.

This is time-consuming work, so use a rotary grinder if possible. Otherwise, you can make do with an assortment of flat and round files. However, use only a round or half-round file when chamfering the edges on round openings, such as the tops of the cylinder bores and the main bearing webbing. If you use a flat file, you'll gouge the surface. After you've chamfered all the edges, smooth them out using 400-grit wet or dry sandpaper.



The casting flash in the square passage above the cam bearing bore

should be removed. A file or die grinder will do the job.



Grinding away the casting flash from the drain-back holes in the center of the oil galley will speed the

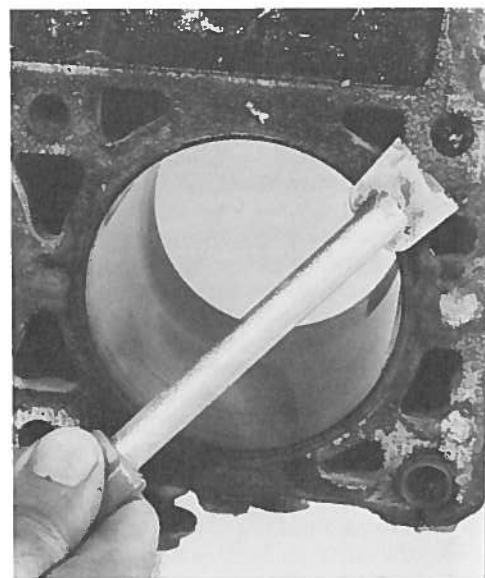
return of oil to the oil pan. It also reduces the number of stress risers.

clearances and crankshaft end play. That way if you need to have something machined for proper clearance, you can have it done well in advance of the assembly process. You can check these clearances by following the procedures outlined in the "Measuring Bearing Clearance" and "Measuring Crankshaft End Play" sections in the next chapter.

After measuring all the clearances and making any necessary corrections, you *must* correctly identify where all the parts were fitted when originally measured to prevent a potentially disastrous mix-up during the assembly process. As insurance against mixing up the parts during assembly, I *strongly* urge you to check all the bearing clearances and crankshaft end play once again.

Camshaft Bearings

Aside from excessive wear, the cam bearings will need to be replaced if you have the block hot-tanked, since hot-tanking destroys them. Replacing the bearings requires special tools and expertise, so save yourself time and money and have your machine shop do it. The shop will use a long rod with a plate screwed onto one end to drive out the old bearings and install new ones. As the new bearings are installed, attention is paid to the alignment of the bearing lube holes



All the debris on the deck must be removed before checking the flatness of the deck. A gasket scraper can be used to remove most debris, and a red ScotchBrite pad will remove the rest.

with the groove that runs around the perimeter of each cam bearing bore in the block.

In some instances, this alignment is so far off that the shop has to install the wider cam bearings from a 350ci small-block Chevy, because these bearings are wider than the stock bearings and allow the shop to compensate for misalignment. However, because of the additional width, these bearings have to be precisely positioned to avoid contact with the cam lobes. Unless you're confident you can do this work yourself, it's better left to the pros.

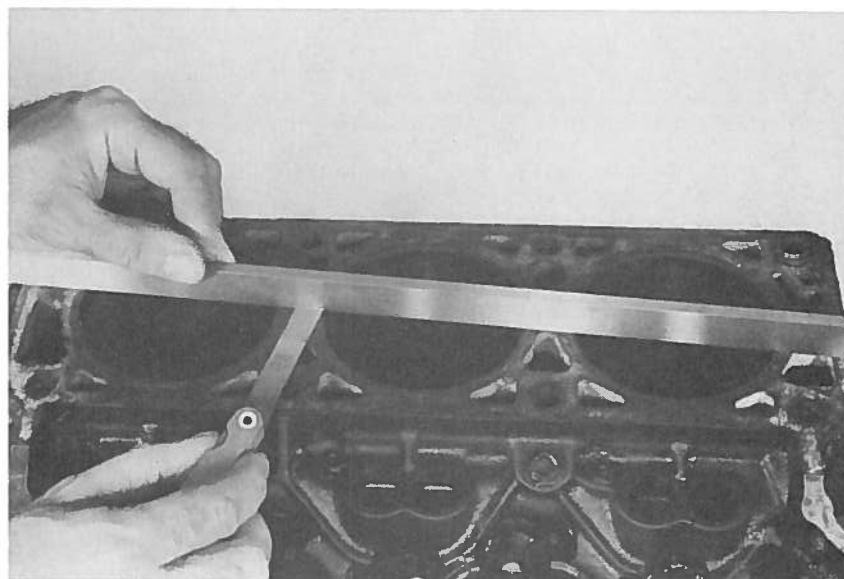
Also, keep in mind that a new type of cam bearing is used in later-model engines. Instead of the traditional babbitt lining, the bearings have a very hard wear surface, similar to that of oilite. These bearings should offer longer service life along with decreased oil pressure loss due to wear. So if you're in the market for cam bearings, you should consider using this later-style design.

Hand Honing

If the piston skirts show minimal signs of wear, and piston-to-bore clearance is within specification, you can get by without having the cylinders honed at a machine shop. Although this isn't the preferred route for long-term durability, installing new rings on old pistons can give the engine a new lease on life.

To ensure that the new rings will seat themselves in the cylinders, you'll need to break the glaze in the cylinders. Either one of two tools can help you do this: a cylinder hone or a ball hone. The cylinder hone uses three or four stones that float on stamped-metal arms. A single spring near the top of the compressor pushes the stones outward against the cylinder. In turn, these stones wear against the cylinder, breaking through the glaze and, if left in long enough, actually take metal off the cylinder walls. This type of tool most closely mimics the honing operation that takes place in a machine shop. The ball hone looks like a cleaning brush with hundreds of silicon carbide balls glued to the ends of wires. When placed in the cylinder, these balls act like scouring pads to break through the glaze.

Before you grab your hone and have at it, you should know that you want to induce as many of the stresses that are present when the en-



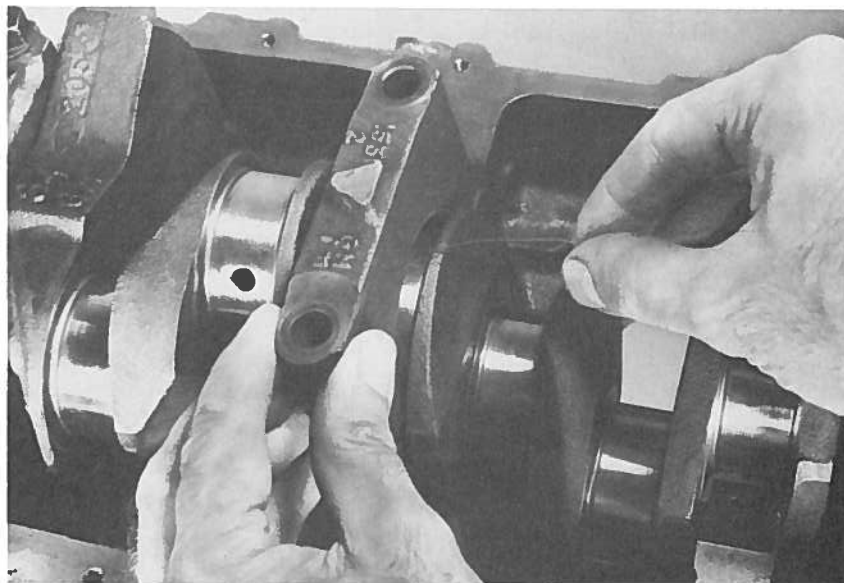
To check deck flatness, hold the narrow side of a straight edge against the deck, then try to slide progressively larger

feeler gauges underneath it. The largest feeler gauge that fits represents maximum deck warpage.

gine is actually assembled as possible. This results in a rounder bore. You can do a pretty good job of simulating this by installing the main bearing caps and torquing them to specifications; if you want to get fanatical about it, you could bolt the heads on

as well. Of course this would require that you hone the cylinders from the bottom, which in turn would require that you cover the combustion chambers with a thin sheet of aluminum to protect them from the hone.

To make a chamber-protecting



Mock-up the crankshaft, connecting rods, and associated bearings at or near the beginning of the reconditioning process. This allows you to have any necessary machine work to correct these clearances completed before you

assemble the engine. To ensure that the parts aren't mixed up after measuring, check bearing clearances and crankshaft end play during the assembly process.

sheet, lay a head gasket over the aluminum and trace the head bolt holes onto the metal. Then drill the holes out so that the head bolts can pass through it. Finally, use the aluminum as a head gasket and install the heads, making sure to torque the head bolts to specifications.

To break through the cylinder glaze, chuck the hone of your choice into a variable speed drill and place it in the cylinder. Run the drill at a low speed while working the tool up and down in the cylinder. Work the tool so that all areas of the cylinder are honed equally, while trying to replicate the 20–32deg crosshatch pattern the machine shop would create. This crosshatch pattern helps the rings seal while preventing excessive ring wear.

Use the hone only until the glaze is broken—maybe 30–60sec minutes per cylinder. When the glaze is broken, the cylinder should feel slightly rough at all points. This roughness will help the rings to seat.

Boring and Honing

If piston-to-bore clearance is beyond specifications, you'll need to take the block to your local machine shop to have it bored and honed. The whole idea behind boring and honing is to make the cylinders as round and as straight as possible. But before you

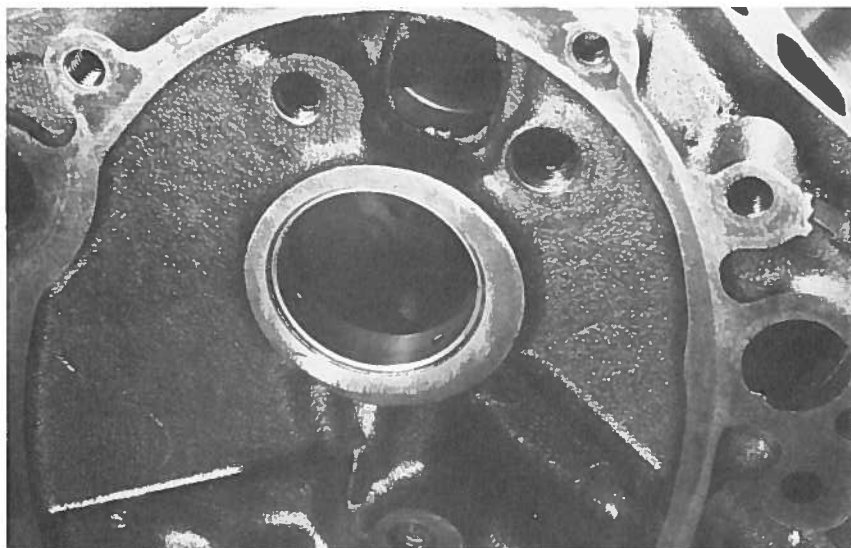
take the block to a machine shop, install the main bearing caps and torque them to specifications as this induces some of the stresses that the block is subjected to during engine operation. And remember, although good equipment is essential to boring and honing, the skill of the machinist doing the work is just as important.

Two types of equipment can be used for cylinder boring. One type is secured to the main bearing saddles on the block, and the other is mounted on the deck of the block. To bore the cylinder, a cutting tool is attached to a boring bar. The bar then rotates as it moves up and down the cylinder, enlarging the cylinder with the cutting tool. Because the cutting tool rips and tears the metal on a minute scale, the cylinder isn't bored to its final diameter. Instead, it's bored to within about 0.005in of its finished size and then honed to remove the rips and tears caused by the cutting tool.

The honing process uses abrasive stones that exert outward pressure against the cylinder bore. These stones are stroked and rotated through the cylinder bore to remove the rough surface left behind by the cutting tool. To ensure the continued presence of fresh abrasive material, the bonding agent in the stones breaks down as the stones are used. This "old" abrasive is flushed away by

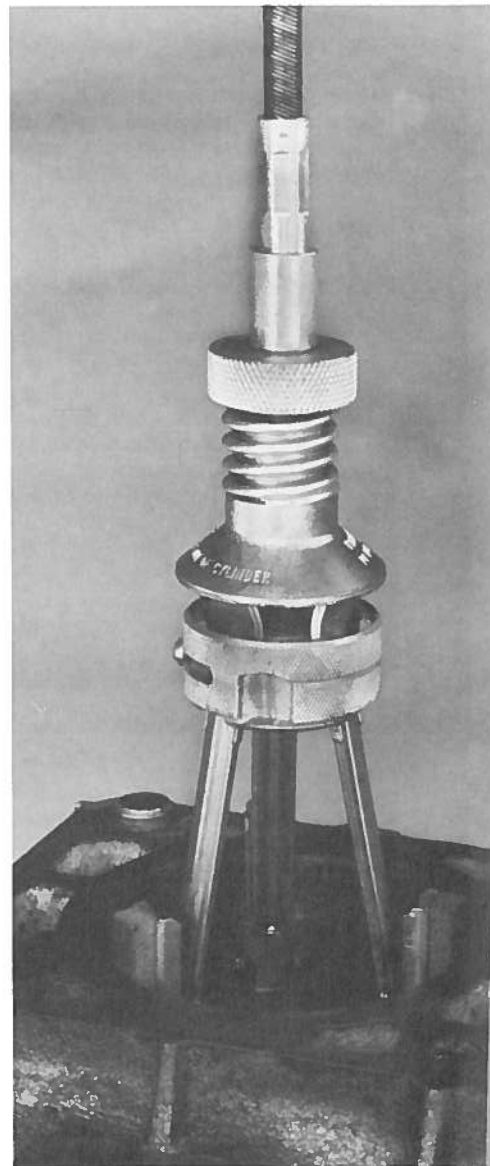
the honing oil, along with the metal that's removed from the cylinder bore.

For the best possible piston ring performance and life, the surface finish on the cylinder wall has to be of a certain smoothness to ensure that the compression rings are properly lubricated. This is dictated by the type of piston rings that are going to be used, such as molybdenum or chrome. Since the compression rings used on the



The camshaft rides on four circular bearings. The front-most bearing has two lube holes, while the remaining bearings use just one. Position of the cam bearing lube hole is critical for main bearing lubrication, since the main

bearings receive their oil from the cam bearings. Positioning the #2, #3, and #4 bearing lube holes at the six o'clock mark provides the best flow of oil to the main bearings. The holes in #1 should be positioned as shown.



Hand-honing used cylinders is a good idea if the piston-to-bore clearances are within specifications and all you need to do is break the glaze and install a new set of rings. Breaking of this glaze is essential to proper seating of the new rings. Check your work often to be sure you don't hone too much.

60deg V-6 are faced with molybdenum, and considering that approximately 20% of the surface of the molybdenum has tiny voids that trap oil, the surface of the cylinder can be quite smooth. This equates to the use of 400-grit stones for the honing operation.

To save time and improve results, the old boring and honing process is falling away in favor of automatic honing equipment. The Sunnen CK-10 is an example of this new equipment. Rather than using a boring bar, it hones the cylinder from start to finish. Because this automatic equipment provides the straightest and roundest cylinder bores, seek out a machine shop that's using it.

Align Boring

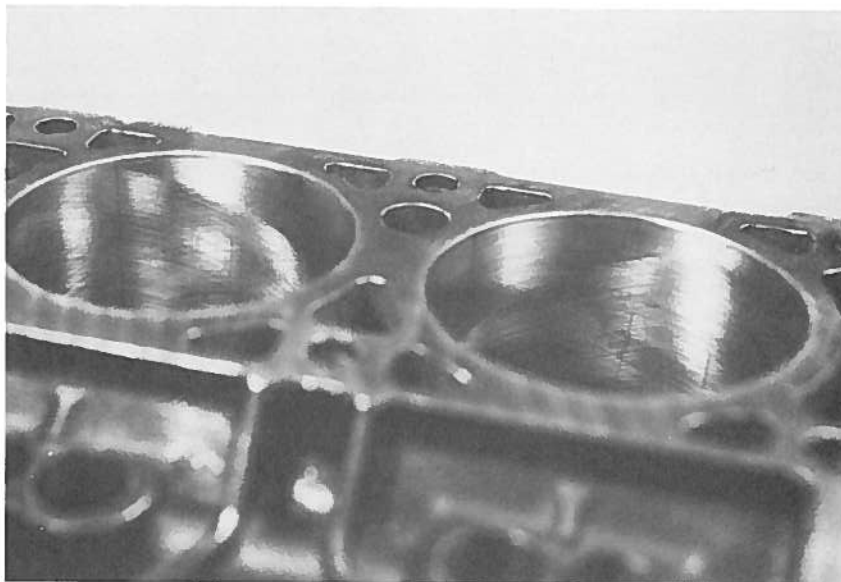
Align boring is a process that's used to correct misalignment of the main bearing caps and saddles in the block. This process entails milling a small amount of metal off the bottom of each bearing cap. Then the caps are torqued to the block and a boring bar is passed through them. Align boring is usually only necessary when a main bearing has spun, since a spinning bearing damages the bearing bores.

Preparing Main Bearings

While you're working on the block, you should check the fit of the main bearings into it. Specifically, check the alignment of the lubrication holes in the upper bearings to those in the block. Proper alignment of these holes is critical to bearing and crankshaft life. Begin this job by thoroughly cleaning the main bearing saddles with brake cleaner. Then place the upper main bearing inserts (easily identified by their lengthwise grooves) in their proper locations in the block.

Remember, in engines with small-journal cranks, the #1 bearing looks like the #2 bearing but it's wider. Because the #3 bearing absorbs the crankshaft thrust, it has short sides. The rear main bearing is the widest. Engines with large-journal cranks almost always use bearings of the same width for the #1 and #4 positions. The #2 bearing is narrower than the others, and the #3 bearing has thrust flanges on its sides.

As you install the bearings, make sure that the tangs on the bearings' ends fit into the square relief in



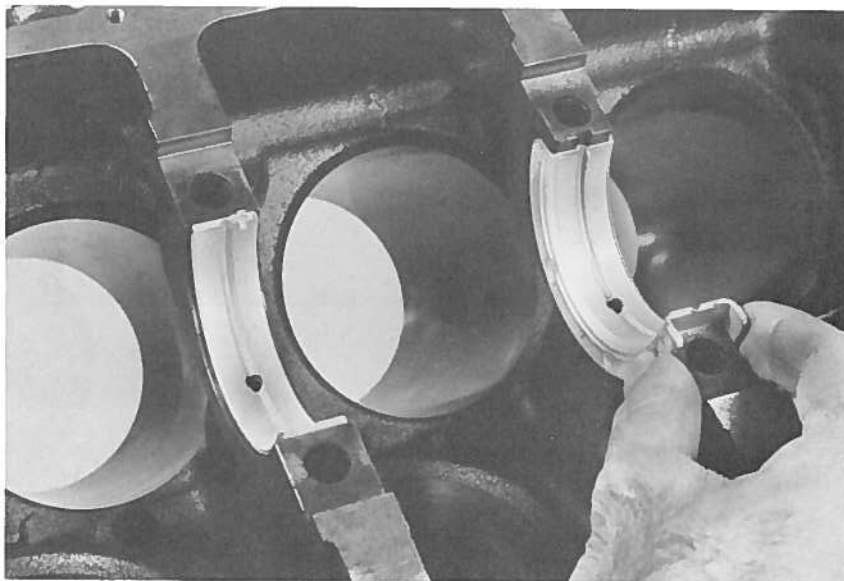
The cylinders of a 60deg V-6 should be honed so that the crosshatch pattern (the angle between the intersecting lines) is 20–32deg. Close inspection of the coolant passages and threaded

holes at the top of the deck reveal chamfering which helps prevent stress risers. Chamfering can be accomplished with a die grinder or file. Do this after the block has been decked.

the bearing saddles and that the bearings are fully seated. You'll probably notice that the bearing has to be compressed slightly to fit into its bore. This is one of the ways the bearing is held in position. You may also notice that when the bearings are fully seated, their ends will protrude slightly above the block. The protrud-

ing ends on the bearings are what is referred to as "crush height."

This additional height works in combination with the crush height of its mating bearing in the bearing cap. Together, these help push the bearing tightly into the bore when you install the bearing cap and torque it to specifications. If you filed the ends of the



After cleaning the bearing saddles with chlorinated solvent, install the main bearings. For maximum oil flow, no mis-

alignment should exist between the lube hole in the bearing and the lube hole in the block.

bearings so they were flush with the bearing bores, they'd spin in the bearing bores during engine operation. Crush height also aids in heat trans-

fer from the bearing to the bearing bore.

With the bearings installed, check the alignment between the lube

hole in each bearing and the lube hole in the block. If the two are just slightly misaligned—on the order of 0.002–0.003in—you can just clean the bearings (and bearing saddles) and install them during assembly. However, if the misalignment is any greater than this or you plan on some heavy-duty use for your engine, your best bet is to remove all traces of the bearing where it overlaps the lube hole.

To do this, make a mental note of where the misalignment is and then remove the bearing. Use a small-diameter, fine-toothed round file to enlarge the hole in the bearing at the point of misalignment. Deburr the hole with a small, tapered stone chucked into a die grinder or drill motor, then recheck the lube hole alignment.

Enlarge the lube hole in the bearing only enough to match the hole in the block, because the more material you remove from the bearing, the weaker it becomes. Use this procedure to prep all the upper main bearings.

When you're satisfied with the lube hole alignment in all the upper main bearings, blow off any debris that's on them and put them in a clean place. It's recommended that you not clean the bearings with any type of solvent as it may damage their soft overlayers.

Regardless of anything else you may have heard, there are no other steps to preparing the bearings. Mistakenly, some people believe that scuffing the bearing wear surfaces helps the bearings break in to the crankshaft, or that applying oil to the backs of the bearings helps increase heat transfer from the bearings to the block. This just isn't true. Bearings work best when their backs and the surface they're mounted to are clean and dry.

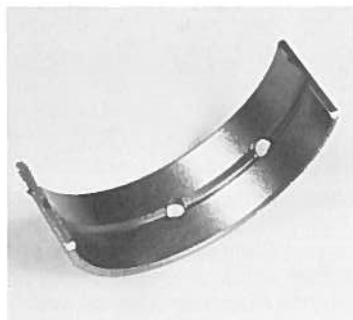
Hot-Tanking

Hot tanking is a process used to clean years of accumulated sludge, varnish, and other residue from engine components—especially the cylinder block and heads. It's also a great way to clean corrosion out of the water jacket in the block, and makes baked on gaskets much easier to remove.

Hot tanking uses a caustic solution that's heated to 175–200degF. The parts soak in this solution for several hours. Any component can be

High-Performance Tip: Improved Oiling

To improve high-rpm connecting rod oiling in pre-1987 engines, the block, main bearings, and crankshaft must be modified. Taking a cue from the later-



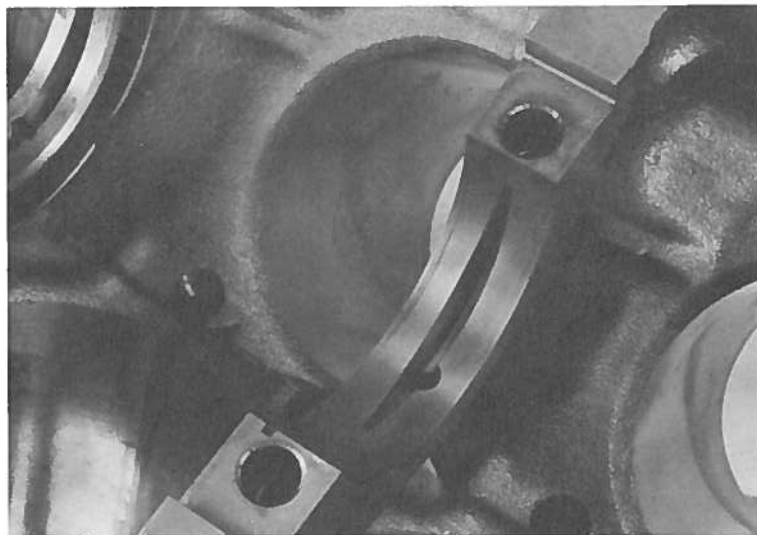
The "extra" lubrication hole (to the right of the center hole) in the upper main bearings helps you take advantage of the lead-in grooves you put in the block, increasing oil flow to the rod bearings. Note that the bearing tang is on the opposite side of the bearing.

style blocks, you need to groove the block's upper main bearing bores. Put one groove in each bearing bore that starts on the right side of the block and opens into the oil feed hole in the center of the bore.

This groove should start on the right-hand side of the block (the side opposite the bearing tang relief) about 1/2in below the bearing saddle and should extend about 3/4in past the oil feed hole. The groove should be approximately 1/8in wide and 1/8in deep and extend directly through the center of the oil feed hole. Taper the ends of the groove until they become shallow and narrow, as this helps decrease oil leakage at the end of the bearings.

To take advantage of this improvement, you need to follow the factory's lead once again and drill another oil feed hole in the lubrication groove in each upper main bearing. This hole should be 1/8in in diameter and positioned about 1in away from the oil feed hole in the bearing.

The crankshaft also needs to be modified in a manner similar to the block. For information on this modification, refer to the "Crankshaft" section in this chapter.



Lead-in grooves in the block are used in later-model 60deg V-6 engines. Adding these grooves to cylinder blocks that lack them increases oil flow to the connecting

rod bearings. This modification must be made in combination with the modification to the main bearings, as described in the text, for full effect.

hot tanked, but a special soaking solution must be used with non-ferrous metals to prevent damage.

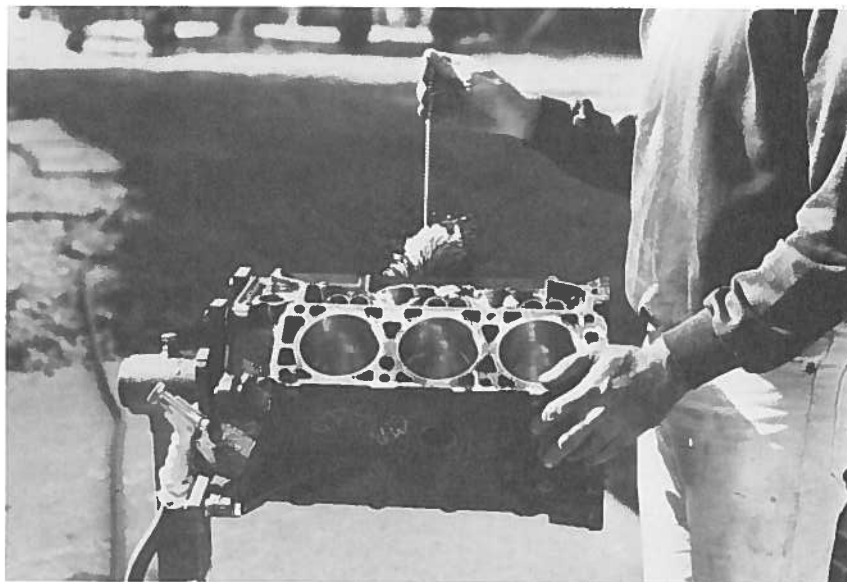
Final Cleaning

After all the work has been completed on the block, you need to clean it thoroughly. Liquid dish soap and a bucket of hot water, along with a garden hose fitted with a spray nozzle, do wonders here. To help clean all the holes and passages thoroughly, you'll also need an engine brush kit consisting of large, cylindrical brushes for scrubbing the entire surface of all the cylinders, smaller brushes with long handles for cleaning out the oil galleries, and cylindrical brushes small enough to clean out the oil passages in the crankshaft. All these areas must be scrupulously clean. You'll need to clean the block out at least two and probably three times to ensure that all the grit and dirt are out of the block. In a pinch, an assortment of rifle cleaning brushes can be pressed into service to clean out the galleries, and larger bristle brushes can be used to clean the cylinder bores and other large surfaces on the block.

If you really want to check to see how clean the block is, poke a clean finger into areas where dirt and sludge normally hide, such as underneath the cam bearing bores. If your finger has any dirt on it, do some more cleaning. When you're sure the block is clean, watch out! It'll rust right before your eyes, and you won't need time-lapse photography to see it happen. Have a roll or two of paper towels on hand, as well as a spray solution that displaces moisture, such as WD-40 or LPS 1.

As soon as you stop spraying the block with water, rotate it one complete revolution on the stand to remove excess water. Then spray all the machined surfaces—the cylinders, lifter bores, main bearing bores, and cylinder decks—with the moisture displacer. When you've finished spraying, blow off the rest of the block with compressed air, paying special attention to cavities and threaded holes. If you don't have access to compressed air, pat the block dry with paper towels. When the block is fairly dry, spray it well with the moisture displacer to prevent rust formation.

Now you need to pay special attention to the cylinder bores. The abrasive material left behind in the cylinders by the honing process is incredibly hard on pistons and rings. As



You'll need to clean the block two or three times to ensure that no grit remains. After rinsing the block for the last time, immediately spray all the ma-

chined surfaces with a moisture displacer, such as WD 40. This will prevent rust.

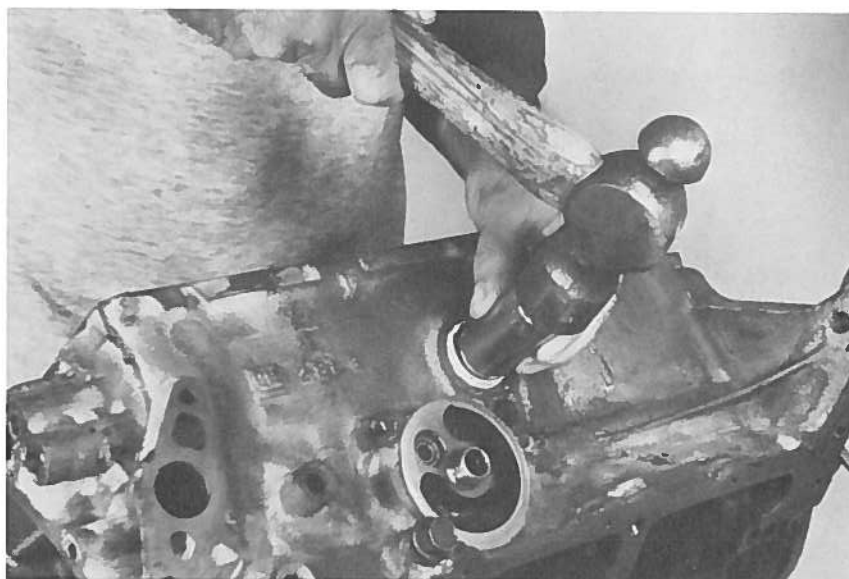
added insurance that all this material is removed, clean each cylinder with a paper towel saturated with automatic transmission fluid. Wipe each cylinder with the paper towel until you think it's clean, then saturate another paper towel with ATF and wipe the cylinder again. You'll know the cylinder's clean if no dark spots appear on the paper towel.

After the block is cleaned, pro-

tect it from dust and dirt by slipping a new plastic trash bag over it and gathering the ends.

Core Plugs

To prepare the core plugs for installation, you can apply a non-hardening sealer, such as Permatex Form-A-Gasket, around the perimeter of the plugs. Alternately, you could use a product like Loctite Stud N' Bearing



After applying sealer to the perimeter of the plug, drive it in, using a deep well

socket and a hammer. When the plug is in position, wipe off the excess sealer.



As added insurance against rust, clean the non-machined surfaces with an etching agent such as phosphorus acid. Apply it wet, let it stand a minute or two, then wipe it off while it's still wet. Don't

let the acid get on any of the machined surfaces, as it will etch them. Then paint the block with high-temperature engine enamel to prevent it from rusting.

Mount. The advantage to using this type of product is that it helps hold the plug in place once it's installed.

When you've applied your sealer of choice, position each plug in its appropriate hole in the block and drive it in using a socket and a brass or lead hammer. To minimize damage to the plug, use the largest possible socket

that will fit into its inner diameter. Drive the plug in squarely until its edge is just below the surface of the block.

Painting

To protect the exterior of the block from rust, and to make it look better, you'll probably want to paint

it. First, clean all the surfaces you want to paint with a wax and grease remover. To help prevent rust, etch the non-machined areas with metal conditioner.

Dilute the conditioner with water per the instructions, then apply it with a small brush. The conditioner must be removed while it's still wet, otherwise the surface will rust even more quickly than it would have if you hadn't used the conditioner. If a surface dries before you can dry it, wet the area again and then wipe it immediately.

After the block has been conditioned, carefully mask off all the machined surfaces. You don't want paint on these areas, because it can have a detrimental effect on sealing. When the block is masked, paint it with five or six coats of high-temperature engine enamel. Don't use regular paint as it can't withstand the heat generated by the engine.

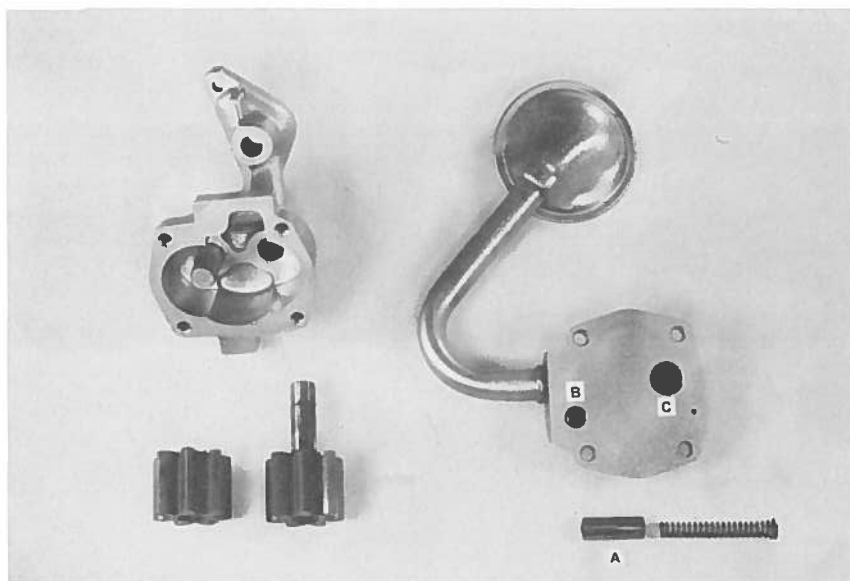
Oil Pump Operation

The oil pump is the heart of the lubrication system. If it can't pump enough oil to meet the engine's demands (a sort of mechanical heart-attack), the engine will die. If this happens, the engine will require a complete overhaul, if it can be salvaged at all (now it's your turn for the heart-attack!).

The oil pump consists of a metal housing, two spur gears, a pressure relief valve, and a calibrated spring. During operation, the two spur gears in the oil pump housing rotate, trapping oil between their teeth. This transfers oil from the intake side of the pump to the outlet side. As the volume of oil becomes too great to be contained in the pump housing, it's forced out of the pump into the oil filter and then through the various oil galleries in the engine. When pressure inside the pump reaches about 80psi, it overcomes the spring pressure that holds the relief valve closed. When the relief valve moves, it exposes the bypass hole, allowing oil to return to the intake side of the pump. This action decreases oil pressure. When oil pressure drops below spring pressure, the relief valve covers the port, and oil pressure builds again. This process repeats itself whenever necessary to regulate oil pressure.

Cleaning and Inspection

Before you spend any time cleaning out your old pump, check to



The oil pump uses two gears to trap oil, then force it out of the pump. The relief valve (A) opens the port (B) in the pump cover when oil pressure gets too high.

Oil is then directed through a passage in the cover and out through a port (C) to the intake side of the pump.

see if the pump body is made of aluminum. If a magnet won't stick to it, you need to replace it with a cast-iron pump.

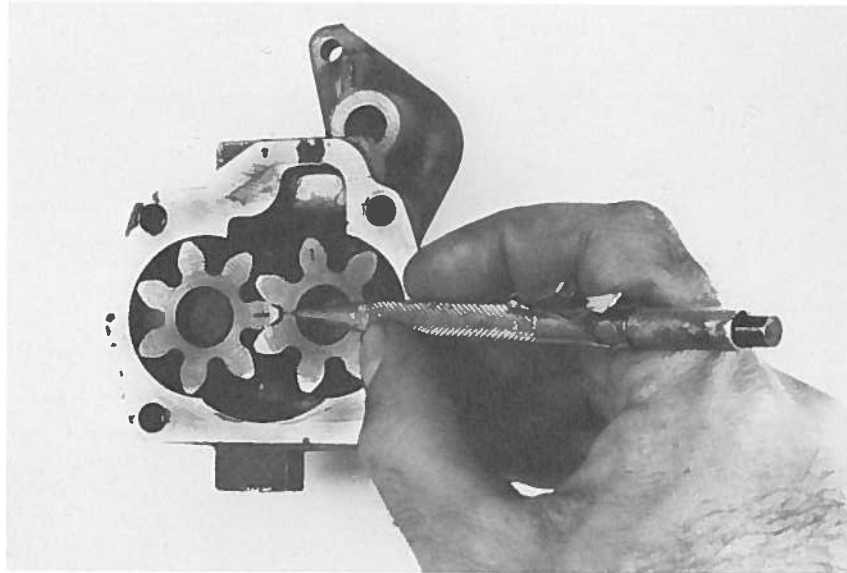
Some aluminum-bodied oil pumps used during the early-1980s had a problem with the fit of the idler shaft to the pump body. If the shaft was on the small side of build specifications and the shaft bore was on the high side, the idler shaft wasn't as positively retained as it should have been, and after awhile, the shaft would move up out of the bore. Once it moved up about 1/4in, the crankshaft counterweight would "introduce" itself to the shaft resulting in the almost instantaneous destruction of the pump and, with it, the engine. Although this problem was resolved shortly thereafter, it's hard to say which aluminum-bodied pumps are good and which aren't. Another problem with aluminum-bodied pumps is that the soft body material would allow end clearance between the pump gears and the cover to rapidly increase as the miles wore on, significantly decreasing oil pressure. All things considered, you're best off to replace an aluminum-bodied pump with a cast-iron bodied one.

On the other hand, if your engine is equipped with a cast-iron pump, begin by cleaning its exterior with a stiff-bristled brush and solvent. This will minimize the amount of dirt that gets inside the pump when you remove the cover. To clean most of the gunk and oil out of the pump, place the pickup in some clean solvent and rotate the driveshaft until the solvent that comes out of the neck is fairly clean.

With the exterior and interior of the pump clean, break the bolts loose on the bottom of the pump, but don't remove them until the bottom of the pump is facing up. This will prevent the gears from falling out. Then remove the bolts and cover.

Now, before you reach in and remove the gears, make an alignment mark across the tooth of one gear into the root between two teeth on the other gear. These alignment marks will allow you to match the gears during assembly, ensuring that the wear pattern between the two gears won't change. When the gears are marked, pull them out of the pump housing.

With the gears out, inspect the ends and teeth on the gears, the interior of the pump body, and the inside of the cover. The spur gears used in



Mark the alignment of the oil pump gear teeth before you remove the gears.

the pump are forgiving of most foreign material that may pass through them, such as minute particles of dirt and bearing particles. However, larger particles can take their toll on the pump gears and body, creating wear and leaving small scratches that reduce pumping capacity.

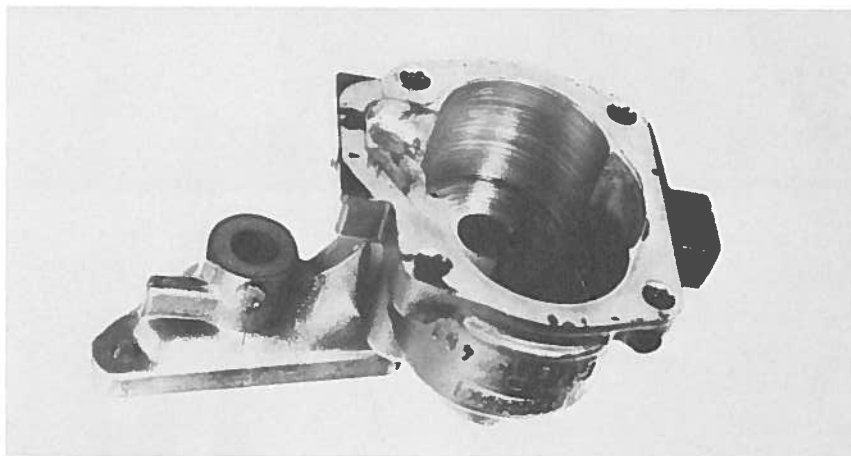
Turning your attention to the pump cover, you may notice light swirl marks where the ends of the gears made contact and minor surface scratches on the gear teeth and in the pump body. These marks are normal. However, if the oil wasn't changed often enough, the air filtration system wasn't doing its job, or metallic parti-

cles circulated through the pump, you'll see deep scratches in the cover, gear teeth, and pump body. You may even find chipped gear teeth. Pumps with this type of wear cannot be salvaged.

Checking End Clearance

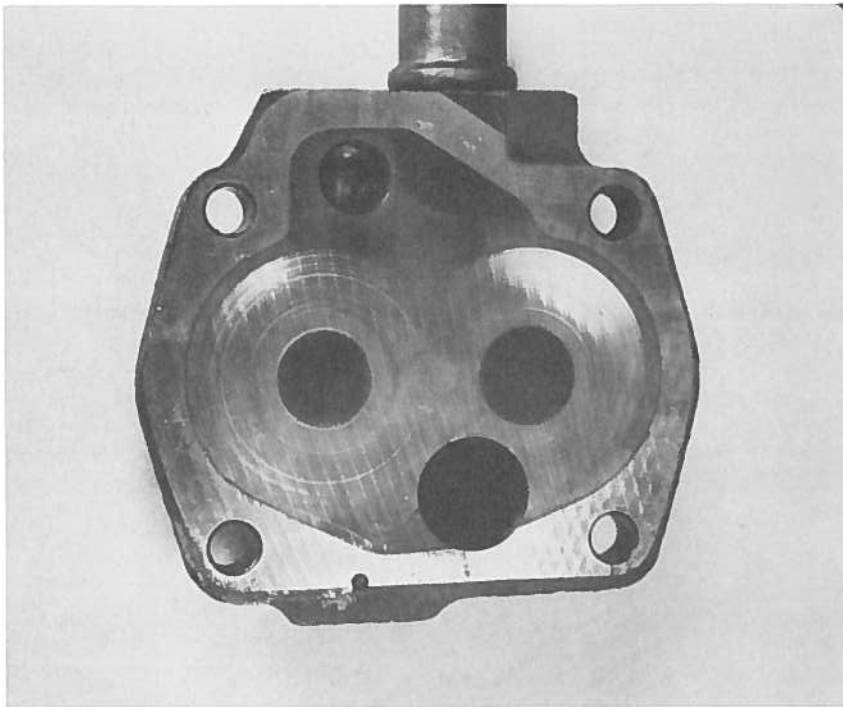
The most important thing to check on your oil pump is the clearance between the ends of the pump gears and the cover. This clearance is critical to pump operation because it directly influences the pump's ability to prime quickly and pump efficiently.

After cleaning the pump gears and body one more time to ensure



If the oil wasn't changed often enough, the interior of the pump housing will become scratched. Scratches deep

enough to catch a nail indicate that the pump must be scrapped.



Minor scratches in the pump cover can be removed by lapping. Deep scratches require pump replacement.

that no oil or grit that could affect end clearance readings remains, hold the body upside down and install the gears. Then slide the cover over the gears so that it partially covers both of them. While holding the cover firmly,

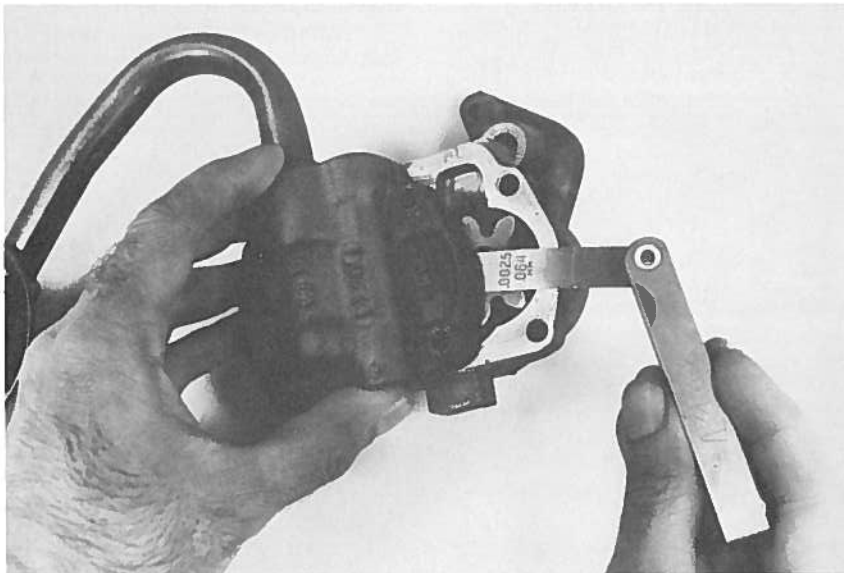
slide the thickest feeler gauge you can between the ends of the gears and the pump cover. This dimension indicates end clearance.

End clearance between 0.002 and 0.005in indicates that everything

is all right, but if it exceeds this, you'll need to reduce it by a type of sanding operation called "lapping." The idea here is to replicate the machining process as closely as possible, which means you want a surface that's as flat as can be. To this end, buy yourself a thick piece of plate glass. Alternately, you could use the table from a drill press, since it was machined flat at the factory. Then lay a piece of 240-grit wet-or-dry sandpaper over it, with the grit facing up, to make your lapping table.

To lap components, wet the paper with water. Then lightly hold the component square to the surface and move it back and forth. After a number of passes, rotate the part 90deg, then continue. Keep rotating the part 90deg after every few passes to ensure that its surface remains square.

If the cover has any scratches, lap it first. This removes the scratches and reduces end clearance at the same time. It also saves you from having to lap the ends of the gears if you reduce end clearance too much by lapping the pump body first. Periodically during the lapping process, stop, clean the cover, and check end clearance again. If you find you've taken too much material off the cover, lap the ends of the gears. Now, if you've removed all the scratches from the cover, but end clearance is still too

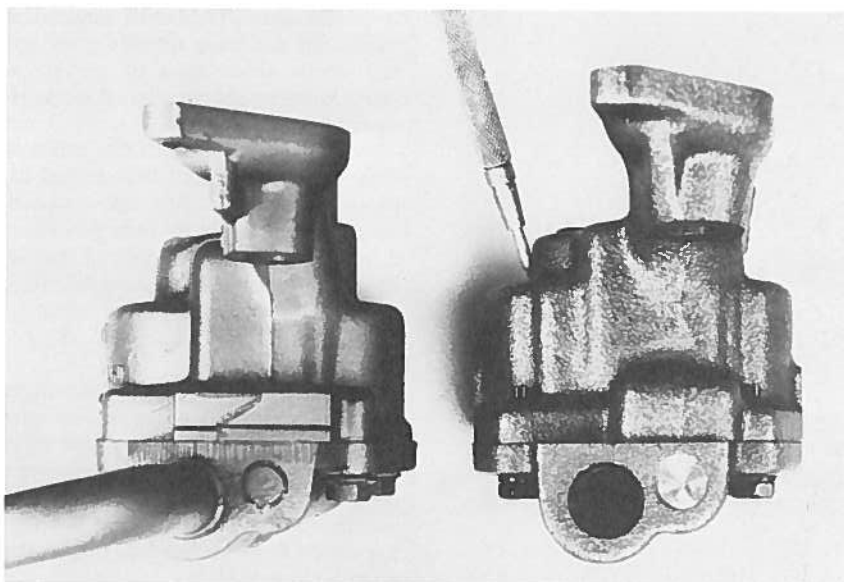


Clearance between the ends of the gears and the pump cover is critical to pump performance. The thickest feeler

gauge that fits between the cover and the ends of the gears indicates end clearance.



Lapping the pump cover, body, and gears can restore proper gear end clearance. Check gear end clearance often to ensure that you don't remove too much material.



A high-volume oil pump can be identified by the depth of the gear pocket in the pump housing. The deeper the gear

pocket, the higher the volume of oil. That's the high-volume pump on the right.

great, remove the gears from the body and lap the body.

Once end clearance is within specifications, clean all the pump components one more time to flush out any remaining grit. You don't want the pump pumping abrasive material through your freshly rebuilt engine. Pay special attention to the pickup as it's a great place for dirt to hide. When the pump is clean, and if you have determined that it doesn't need to be replaced, skip the next few paragraphs and read about how to increase oil pump pressure, an improvement practically all 60deg V-6s can use.

If after your checks and measurements you determine that the pump is worn excessively, replace it with an equivalent pump from GM or a brand-name manufacturer, such as TRW or Mellings. In all cases, use of a high-pressure, high-volume oil pump is strongly recommended. Since the clearances on the 60deg V-6 tend to be on the loose side, using a high-pressure, high-volume oil pump will give you added assurance that all the internal components are getting enough oil. If you couple this type of pump with a crankshaft that's been ground to help minimize oil loss, the lubrication system will be fairly bulletproof.

Although most engine component manufacturers include a high-pressure, high-volume oil pump in their engine overhaul kits, check with

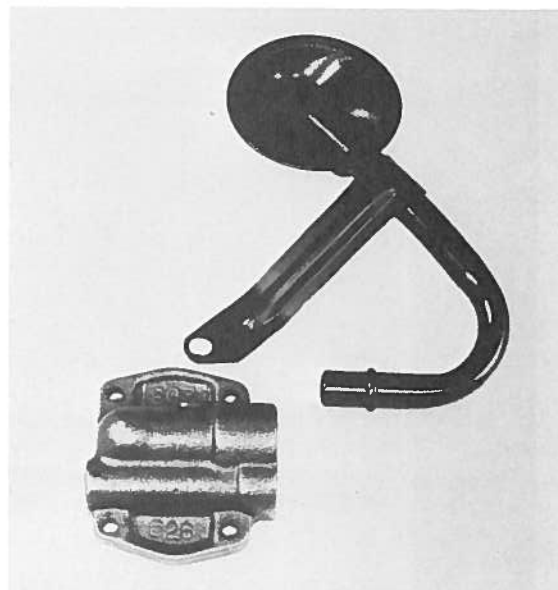
your supplier to be sure. A high-volume pump can be identified by its longer pump body and longer gears versus those of the stock pump.

When using a new oil pump, make sure you don't reuse the pickup from an old pump. It may harbor all sorts of dirt and grime that will be sucked into your newly rebuilt engine as soon as you start it. If you opt to purchase a factory oil pump, order a pickup for it as well, as the new pump won't include a pickup.

Increasing Oil Pump Pressure

If you can't afford a new high-pressure, high-volume pump, you can rework your old pump so that it will pump with increased vitality. To increase oil pump pressure, you can use a stronger spring behind the oil pump relief valve, or you can shim the spring with small washers. A stronger spring is available from your local GM dealer as part number 10044435 and is marked with a blue stripe. Alternately, you can shim the spring with small washers. The problem with using small washers to shim the spring is that you don't know whether you've installed too many washers until the pump is in the engine and running. And if oil pressure goes too high, you can blow the seal on the oil filter or, in severe cases, the metal shell of the filter. Obviously, this isn't the best way to increase pump pressure.

To replace the stock relief valve

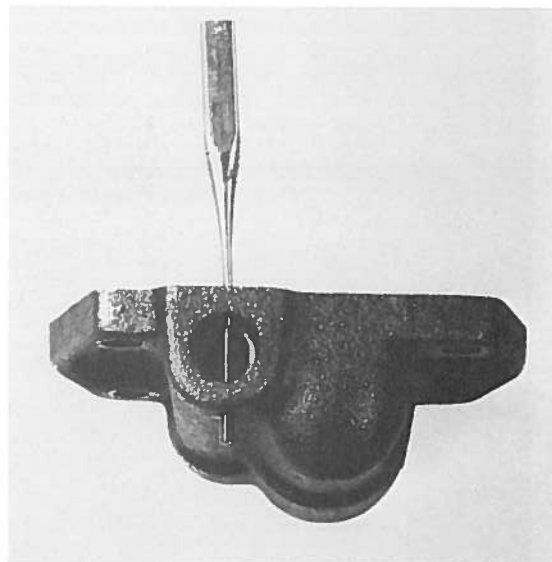


Be sure to use a new pickup on a new oil pump. The bracket on this pickup bolts to the oil pump cover for additional stability.

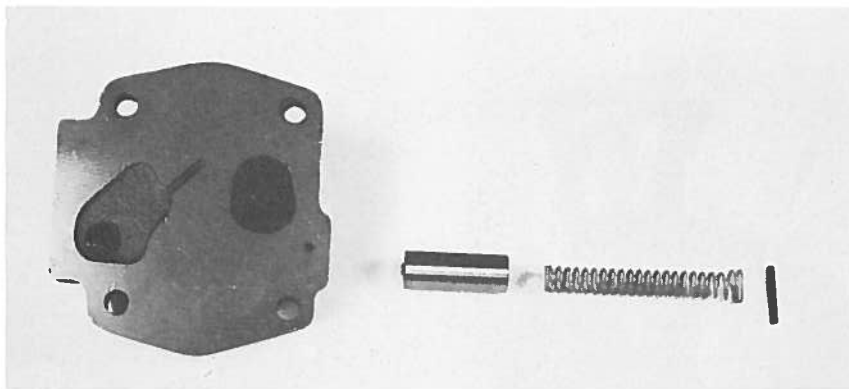
spring with the high-pressure spring, you have to remove the relief valve.

Relief Valve Removal

To remove the pressure relief valve and spring from the pump cover, chuck the cover in a soft-jawed



Remove the retaining pin in the cover with a small-diameter punch. Hold a rag over the end of the relief valve bore as you remove the retainer so that you don't get injured by the relief valve spring.



The relief valve spring determines maximum pump pressure. Pump pressure can be increased by inserting small washers between the end of the spring

and the retaining pin, or by replacing the relief valve spring with part number 10044435 from a GM dealer. This spring is color-coded with a blue stripe.

wise, or, in a pinch, have a friend hold the edge of the cover that contains the roll pin over the edge of a table. Then use a punch to drive the pin halfway out of the cover.

Next, put your thumb over the valve bore and remove the roll pin with a pair of pliers. Put your hand underneath the valve bore, and then

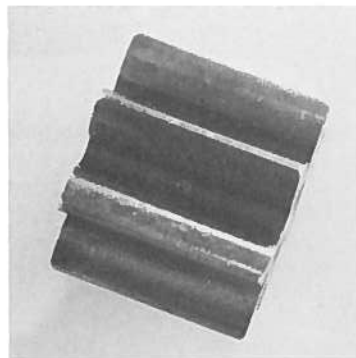
tip the cover so that the spring and valve slide out. If the valve hangs up in the bore at the hole for the roll pin, it's probably blocked by a burr from the roll pin hole. Deburr the hole with a fine file, then remove the valve.

If the valve is difficult to remove from the bore, apply only 1 or 2psi of air pressure at the relief port in the cover.

High-Performance Tip: Oil Pump Improvements

In the endurance racing world, many modifications are made to improve engine durability. Some of these improvements are strictly for the racetrack in that they require frequent parts inspection and replacement, but other improvements can be adapted to the street and will result in a more durable and/or better-running engine.

When it comes to wet-sump oil



A 1/16in hole in the root between two teeth on the idler gear will ensure that the idler gear shaft lives a long and happy life.

pumps, there's a couple of modifications that fit this latter description.

For example, a 1/16in hole can be drilled into the root between two teeth on the idler gear of a wet-sump oil pump. This modification ensures that a good supply of oil reaches the idler gear shaft, minimizing wear. As you drill, be sure not to damage the gear teeth. Remove any burrs from the finished hole so that they don't damage the gear teeth. A small round file or grinding stone can help you here. And don't drill more than one lube hole, as oil pump pressure can drop markedly.

A second modification entails matching the oil exhaust port on the oil pump with the oil pump passage in the bearing cap. A misalignment here can cause oil foaming and heating which will decrease engine longevity.

To check for misalignment, make a template of the oil pump neck out of heavy paper. Use the dowel holes on the neck for alignment, and cut a hole in the paper that exactly matches the oil exhaust port in the pump neck. Then slide the dowel holes in the template over the dowels on the bearing cap. If there's a mismatch between the hole in the template and the hole in the cap, use a die grinder or file to make them match.

Caution: This will expel the valve. In no case should you apply more than 2psi of air pressure; otherwise you may be seriously injured.

If you can't remove the valve, or if the surface of the valve is galled, replace the oil pump. The valve is probably not moving in its bore as fast as it should when the engine is operating, which can cause excessively high or low oil pressure.

Valve Installation

As you're installing the high-pressure relief valve spring, be sure that its small end fits inside the valve and that its large end is against the roll pin. If the spring is installed backwards, oil pressure will soar, destroying the oil filter gasket and maybe the engine along with it.

Crankshaft

The crankshaft for the GM 60deg V-6 engine is made of cast-nodular iron and uses rolled fillets on the two centermost main bearing journals and on all six rod journals to increase its strength.

Two versions of this crankshaft have been produced: externally balanced and internally balanced. The externally balanced crankshaft uses only two counterweights, one at each end of the crankshaft for balance. Since these counterweights don't have enough mass to achieve final engine balance, a counterweighted flywheel or flexplate is also needed. Externally balanced crankshafts were installed in all engines from 1980 through the 1986 model year.

The internally balanced crankshaft was introduced in 1987 and was designed primarily for engines equipped with a Distributorless Ignition System. To provide a reference for crankshaft timing of the DIS, a slotted timing disc was added to the center of the crankshaft. This disc added enough mass to the crankshaft that it could be internally balanced. Consequently, no counterweights are required on the flywheel or flexplate. This crankshaft was used in all engines destined for front-wheel-drive vehicles starting in 1987 and in all engines intended for rear-wheel-drive vehicles from model year 1988 to the present.

Several internally balanced crankshafts also feature lead-in grooves in the #2 and #3 main bearing journals. These grooves substantially

High-Performance Tip: Lead-In Grooves

The lead-in grooves in the main bearing journals work so well that it's a good idea to perform this modification to early crankshafts that lack them. These grooves should start about 1-1/4in before the oil feed hole in each main journal. They need to be about 1/8in deep at the feed hole and about 3/16in wide, and then gradually taper off. Keep in mind that to be effective, they must be placed to the right side of the oil feed hole when you're looking head-on at the front of the crankshaft. When combined with the modifications earlier outlined in the "Preparing Main Bearings" section, these modifications significantly increase the volume of oil to the connecting rod bearings.

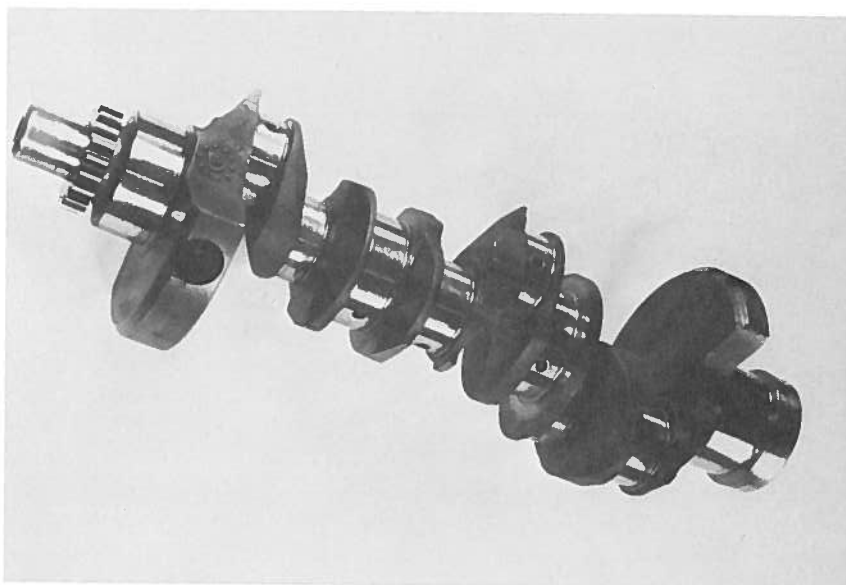
If you have a 1987 or later engine, your crankshaft may not use lead-in grooves. That's because the factory changed the drilling in the crankshaft to allow more oil to flow to the connecting rod bearings and lead-in grooves in the crankshaft were no longer necessary.

increase the flow of oil to the rod bearings.

You should also be aware that the main bearing journals vary in size, depending upon the model year of the engine in question. All 1980-1984 and some early-production 1985 engines feature crankshaft main bearing journals that are 63mm (2.494in) in diameter. To increase durability, all engines produced after this use 67mm (2.648in) diameter main bearing journals.

High-Performance Tip: Long-Throw Crankshaft

The crankshafts used in 3.1- and 3.4-liter engines have longer rod throws than the crankshafts used in 2.8-liter engines (84mm versus 76mm). If you have a hankerin' to increase the displacement of your 2.8-liter, you can do so by using one of these cranks. However, your engine would have had to have been originally fitted with a large-journal crank to accept the large-journal 3.1- or 3.4-liter crank. And if you decide to use this factory "stroker" crank, you'll need to check the clearance between the rods and the side of the block. If the rods contact the block as you rotate the crank, you'll need to remove metal on the block and/or rods to gain the desired 0.020in clearance.

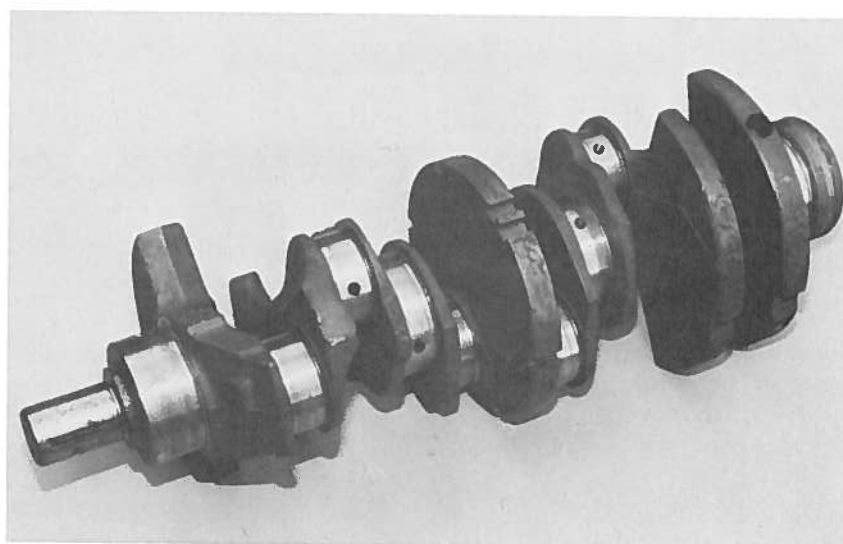


Externally balanced crankshafts use only two counterweights: one at each end of the crankshaft. A counter-

weighted flywheel or flexplate is needed to balance it.

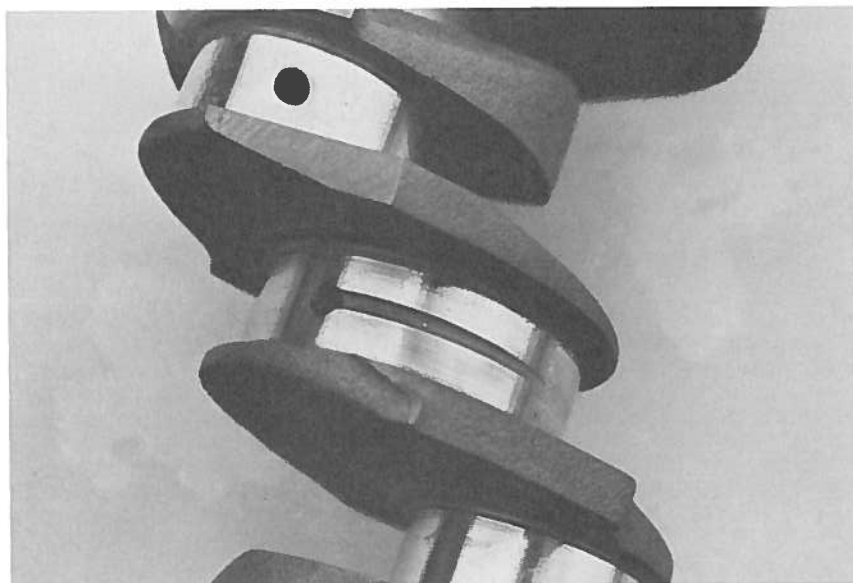
Casting #	Type of Balancing	Journal Diameter	Type of Rear Main Seal Surface	Type of Original Seal
504	External	Small	Knurled	Rope or two-piece
504	External	Small	Smooth	5mm one-piece
209	External	Large	Smooth	10mm one-piece
817	External	Large	Smooth	10mm one-piece
481	Internal	Large	Smooth	10mm one-piece
526	Internal	Large	Smooth	10mm one-piece

Note: This is only a partial listing of factory-installed crankshafts.



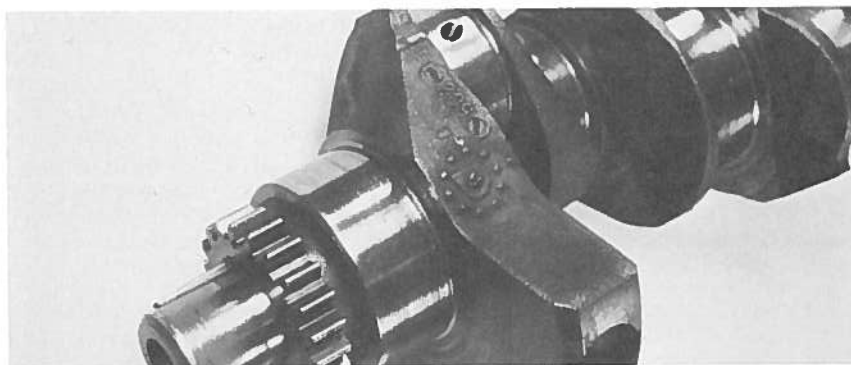
The disc in the middle of this crankshaft provides a reference for the Distributorless Ignition System (DIS). The weight of the disc eliminates the need for counterweights on the flywheel or flexplate. The notches in the disc serve as a ref-

erence point for the DIS used in front-wheel-drive cars. Starting in 1988, this crank was used in rear-wheel-drive applications, but it didn't have the notches cut into the disc because they still used distributor-based ignition systems.

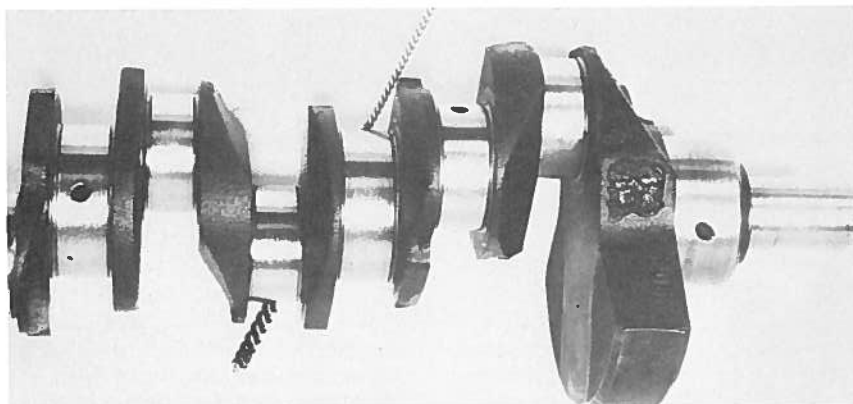


Lead-in grooves on the #2 and #3 main bearing crankshaft journals allow more oil to reach the rod bearings, which ex-

tends their lives. This is a worthwhile addition to any high-performance 60deg V-6.



The casting number on the crankshaft's front counterweight can help you identify your engine's crankshaft.



Use a small-diameter brush to clean any debris from the oil passages. A gun cleaning brush can be used in a pinch.

To identify your crankshaft, use the casting number on the front counterweight.

When replacing the rear main seal, use a 5mm one-piece seal to replace the rope or two-piece seal on a small main journal crank. This will minimize the chances of oil leaking past the seal.

Cleaning

Cleaning the crankshaft is a three-step process. First, clean the exterior with a cleaning solvent such as Gunk and a stiff-bristled (non-wire) brush. (Wire brushes can damage the surface finish on the main and rod bearing journals.) Second, clean all the oil passages in the crankshaft with a small-diameter nylon brush, taking extra care to make sure the holes are free of all contaminants. Third, clean the exterior of the crankshaft once again to ensure that no grime remains, and blow out all the oil passages with compressed air. Be sure to wear safety glasses.

Inspection

When the crankshaft is clean, carefully inspect the rod and main bearing journals. Journals in good condition are shiny and smooth and show no signs of discoloration. On the other hand, journals that are rough usually indicate that the oil wasn't changed often enough and/or the air filtration system isn't doing its job. Deep scratches or scoring means the crank will have to be ground. Also look for cracks. Cracks in the crankshaft usually start at the oil supply passages and work their way out toward the sides of the journal.

If you find an area that looks like it's cracked, you can check it using the dye penetrant method of crack detection covered at the beginning of this chapter, or you could show it to your local machinist and ask his opinion. He may suggest having the crankshaft Magnafluxed. If the crankshaft has any cracks, it must be replaced. If you suspect a crankshaft is cracked, you should always have it Magnafluxed before having it machined. That way, if the crankshaft is cracked, you haven't wasted your hard-earned money on the machining.

When you're checking the crankshaft for signs of abnormal wear, you should also look at the bearings. Generally speaking, the bear-

Engine Bearings

Engine bearings are incredible feats of engineering. Not only are they strong enough to withstand the violent acceleration and deceleration of the pistons, rings, and connecting rods, they are gentle enough to mold themselves around the crankshaft journals and absorb minute particles from the oil.

The bearings in your 60deg V-6, like practically all other engine bearings, are of the sleeve-type. When viewed from the side, they look like a half circle. Two of these bearings are mated to each other to form a full circle. They're used at various points on your engine's crankshaft and at the bottom of each connecting rod.

Sleeve-type bearings are used because they offer a very high load-carrying capacity and can last for 100,000 miles or more. These bearings work in combination with the oil supplied by the engine oil pump.

Before an engine is started, the crankshaft journals are lying directly on the lower main bearings. As the engine is cranked, oil is supplied by the oil pump, through the crankshaft, to the bearings. The oil is drawn around the rotating crankshaft by hydrodynamic action, encapsulating it and making it rise off the main bearings. When crankshaft speed is constant, oil is evenly distributed around the journals.

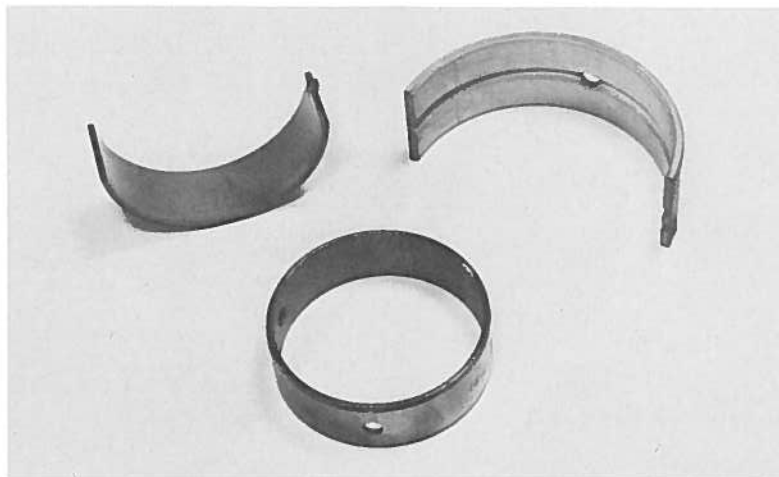
If the engine is accelerated or decelerated, the crankshaft squeezes the oil film, making it thinner. Under extreme conditions, such as lugging the engine, the forces acting on the crankshaft can cause the crankshaft to squeeze the oil out from between the journals and bearings, causing the crankshaft journals to touch the bearings. Although the bearings are designed to handle this type of abuse intermittently, you want to avoid this situation if at all possible.

Manufacturing

If you're not familiar with sleeve-type bearings, you're in for a shock when you first look at them. Unlike ball or needle bearings, sleeve bearings use no rolling components to reduce friction. Instead, they use oil.

The clearance between the bearing and the rotating crankshaft is calculated to keep a film of engine oil in place. Since oil bonds more tightly to metal than to itself, it "slips" on itself, reducing friction between the bearing and crankshaft, as well as dissipating the heat from these components.

To help bearings stand up to the punishment a crankshaft can bestow, they're typically made of three or four different types of metals. The bearing "foundation" is usually an aluminum or steel shell. This provides the load car-



Engine bearings can be smooth or grooved or have one or more oil feed holes.

rying capacity. On top of this foundation, a softer metal or alloy is used, such as copper mixed with lead. This material isn't as strong as the steel, but it's much more forgiving if the crankshaft touches it, which can happen if it's severely overloaded. The "topcoat" over the copper and lead alloy is typically Babbitt, a relatively soft alloy consisting of lead, tin, and a small percentage of other materials, which can absorb minute particles in the oil that would otherwise abrade the crankshaft. It also has a low coefficient of friction, which enables the crankshaft to momentarily come in contact with the bearing without immediate problems, such as seizure.

Crankshaft bearings use a system of oil holes and grooves. The holes allow oil to pass from the block into the space between the bearing and crankshaft. The grooves help distribute oil around the surface of the crankshaft journal.

Connecting rod bearings don't use any oil holes, because they are fed lubricant via holes in the crankshaft. Rotation of the connecting rod around the crankshaft helps distribute the oil.

Engine bearings possess a combination of certain characteristics, including:

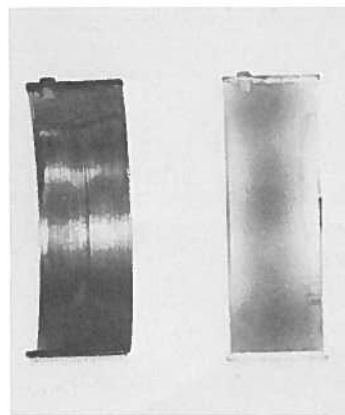
- **Fatigue strength:** The load a bearing can stand before it fails.
- **Conformability:** A bearing's ability to flow and conform itself to a slightly irregularly shaped journal.
- **Embeddability:** A bearing's ability to absorb minute particles that would otherwise damage the crankshaft journals.
- **Corrosion resistance:** The ability of a bearing to resist the acids that are

formed as a by-product of the combustion process.

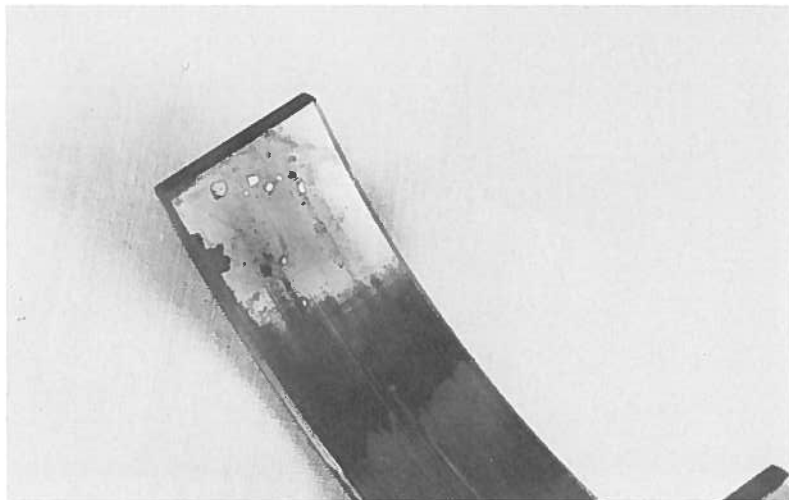
- **Thermal conductivity:** A bearing's ability to absorb heat from the engine oil and transfer it from the surface of the bearing to the bearing bore.
- **Temperature strength:** The ability of a bearing to carry a load throughout the engine's range of operating temperatures without flowing out of shape.
- **Surface action:** The frictional properties of a bearing to resist seizure if the crankshaft comes in contact with it during engine operation.

Because optimizing some of these qualities reduces the characteristics of the others to an unacceptable level, all bearings are a compromise of these qualities.

continued on next page



The bearing with normal wear (except for the scratch in the middle) is shown on the left. A new bearing is on the right.



Some of the material that scratched these bearings is lodged in the bearing

surface just below the parting line. It appears as white spots in this photo.

Reading Bearings

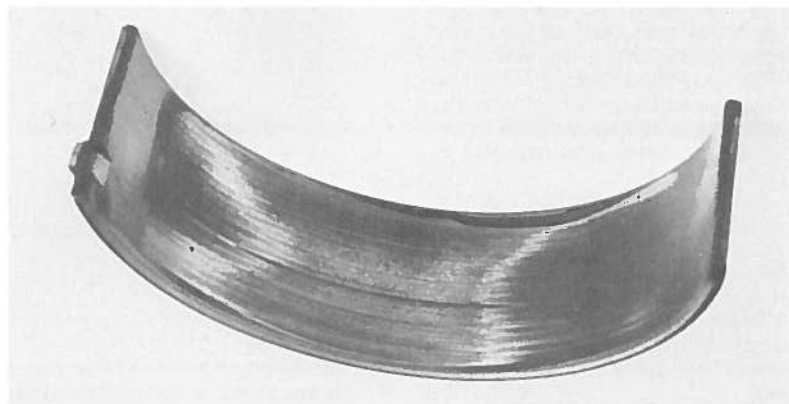
Learning how to decipher the cryptically written messages on used engine bearings will tell you much about the condition of your engine. For example, bearings can tell you whether the crankshaft journals are out-of-round or tapered. They can also tell you if the oil has been changed frequently, or if a connecting rod is bent or twisted.

Far and away, the leading cause of bearing failure is dirt on the components during assembly. Misassembly and misalignment are tied for honors for second place, and insufficient lubrication and overloading round out the top five causes of bearing failure. Although each of these problems can happen separately, they usually occur together. The important thing is to determine what actually caused the failure and correct it so that it doesn't oc-

cur again. Simply slapping a new set of bearings in will not cure the problem.

Normal Wear. A bearing that's led a normal life will show wear over 66–75% of its wear surface. The wear pattern will be even and you should see no evidence of another color showing through the wear area. Bearings with normal wear should be replaced with bearings of equal or greater quality and strength.

Surface Fatigue. A surface fatigued bearing will have cracks and pits along the length of its lining. This type of wear is usually the result of the bearing's life being exceeded. If the bearing was in the engine for more than, say, 50,000 miles, replace it with the same type of bearing. However, if the bearing lasted fewer than 20,000 miles, upgrade to one of the premium bearings offered by such companies as Glacier-Vandervell or Michigan "77."



This bearing died from an insufficient supply of oil.

Dirt in Bearing Wear Surface.

Scratches in the bearing wear surface, in combination with foreign particles, indicates metal shavings or dirt in the engine oil. These particles dig into the bearing, displacing metal and resulting in high spots. These high spots become worn by the crankshaft. The most probable cause for this type of problem is careless cleaning before assembly. However, it can also indicate a problem with the air filtration system or wear of internal engine components.

Dirt Behind Bearing. If you see distinct areas of localized wear on the bearing lining, possibly combined with small areas where lining is missing, look closely at the bearing back. If you see localized discoloration or missing chunks of metal, dirt was probably behind the bearing, causing a peak to form on the bearing wear surface. The rotating crankshaft journal caused this area to heat up and become discolored. This type of problem is the result of insufficient cleaning of the bearings and/or bearing bores.

Insufficient Oil Clearance. If the bearings have very shiny wear surfaces or scratched areas that run the length of the bearing, chances are the bearing died from a lack of oil. Many things can cause this problem, including an insufficient oil supply, insufficient bearing clearance, plugged oil passages in the block or crankshaft, excessive connecting rod side clearance, overrevving the engine, not pre-lubricating a new or rebuilt engine, or a faulty oil pump.

Excessive Oil Clearance. If only a small portion of the center of the bearing is worn, and this area is highly polished, check for excessive clearance between the bearing and crankshaft journal. Excessive oil clearance can be corrected with new bearings that provide the proper clearance.

Poor Journal Finish. Fine scoring marks on most of the bearing wear surface usually indicate that the finish on the crankshaft journal the bearing was fitted to is poor. The rough finish on the crankshaft penetrated the oil film, abrading the bearing. The cure for this problem is to have the offending journals ground and then polished. Be sure to replace the affected bearings.

Excessive Crush. Bearings with excessive crush will have extreme wear near their parting lines. The parting line is the edge of the bearing where the upper and lower bearings meet. This type of damage is usually the result of the bearing cap being overtightened and/or filed in an attempt to reduce bearing clearance. Both of these techniques will cause the parting lines of the bearings to fold inward. The

continued on next page

folded areas then contact the crankshaft journal, causing extreme wear. If bearing clearance is incorrect, use bearings of a different size, have the crankshaft journals ground, or both. *Never* reduce the height of the bearing caps by any means. And remember to always torque bolts and nuts to specifications.

Insufficient Crush. Insufficient crush reveals itself as polished areas of the back of the bearing. A bearing with this problem doesn't have enough radial pressure on it to keep it from spinning in the bearing bore. The polished areas are the result of the bearing spinning in the bore. Many things can contribute to this problem, including a stretched bearing cap or oversized bearing bore. However, the most likely causes for this problem are insufficient torquing of the bearing cap bolts or nuts or dirt between the bearing cap and main bearing saddle or connecting rod.

Bent Crankshaft. Bearings that are used with a bent crankshaft have damage that's usually concentrated in the center most bearing, then fades as it moves to the endmost bearings. To see this, you need to lay out the bearings according to their positions in the block. If the crankshaft was bent before or during installation, you'll see this type of wear pattern. Lugging or over-revving can cause the crankshaft to bend after it's been installed.

Misshaped Journal. Misshapen journals usually cause one of three wear patterns on bearings. The wear pattern can be concentrated in the middle of the bearing, or on both outside edges of the bearing with minimal wear in the middle, or on just one edge of the bearing with the wear tapering away toward the other edge of the bearing. If your bearings fall into either of these categories, the crankshaft journal is probably out of shape. A misshaped journal puts an uneven load on the bearings and can decrease bearing clearance enough so that the oil between the journal and bearing is pushed out. Without oil, the bearing wears rapidly. The first two wear patterns discussed above are caused by barrel-shaped or hourglass-shaped journals, and can only be caused by improper machining. However, the third wear pattern can be the result of improper machining or misaligned connecting rods.

Selecting Replacement Bearings

When choosing bearings, you'll be time and money ahead by buying high-quality replacements. The names Clevite "77" and Michigan "77" come readily to mind. General Motors also

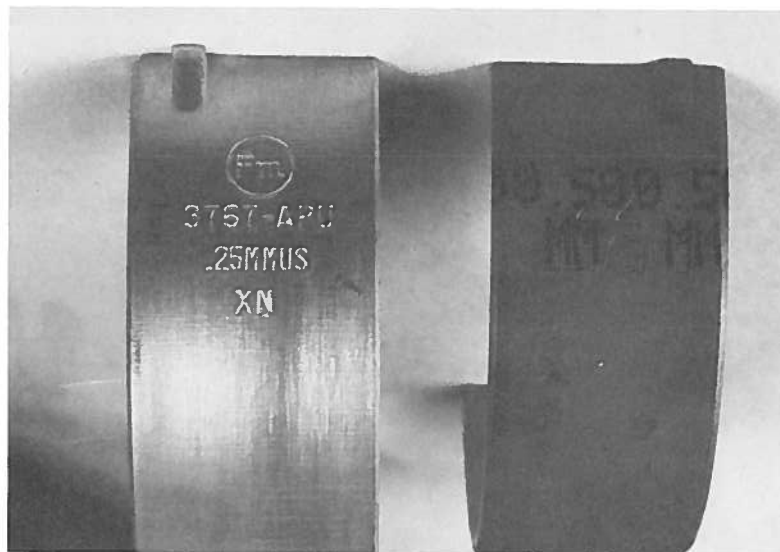


Clevite "77" engine bearings are renowned for their strength and durability. Each upper and lower bearing

set has the name stamped in it, along with the date of manufacture and stock number.

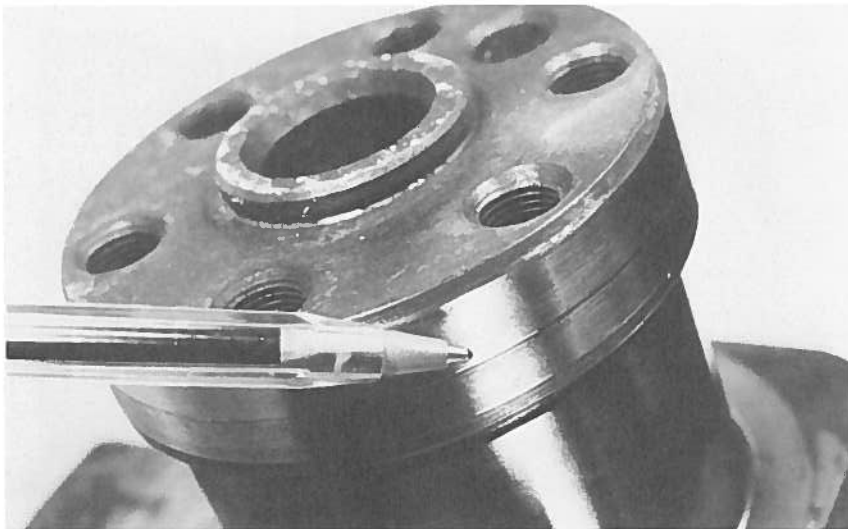
has a good bearing in their Moraine 400 series. Whichever bearings you choose, their installation is of utmost importance. Incorrect assembly or dirt can drastically shorten a bearing's life and flatten your wallet at the same time. The back of bearings must be dry

and should be directly installed from the packing box. Cleaning of new bearings, is not recommended because it can remove some of the soft metal overlay on the bearing wear surface, which absorbs minute contaminant particles.



Undersize bearings are marked as such on the back of the bearing. The bearing on the left is stamped

".25MMUS." The "US" is short for undersize. The bearing on the right has its size (.500mm) sprayed on.



Over a period of time, the lips of the rear main seal can cut into the crankshaft. If this groove is deeper than

0.003in, you should sleeve the back of the crank.

ings take most of the abuse. Refer to the bearings sidebar in this chapter for more information.

When inspecting the crankshaft, also look at the sealing surface for the rear main seal. After awhile, the lips of the seal can cut a shallow groove in this surface. If this groove is deeper than about 0.003in, it needs to be repaired.

If your crankshaft uses the 5mm seal, you'll need to have the crankshaft welded up and then reground.

On the other hand, if your engine uses a 10mm wide-rear main seal, a sleeving kit is available to repair the damage. This sleeve is similar in design to the kits used to sleeve the engine damper.

To install the sleeve, clean the sealing surface on the back of the crank with a chlorinated solvent. Then look at the rear edge of the sealing surface. This edge must have a 45deg, 0.050in wide chamfer to accommodate the leading edge of the

sleeve. If your crank doesn't have this chamfer, make one using a die grinder or file.

With the back of the crank chamfered, try to slide the sleeve on. It should slide on about 1/8in or so. If it doesn't, lightly dress the sealing surface of the crank with some 400-grit sandpaper as outlined in the "Polishing Journals" section in this chapter. When the sleeve can slide just 1/8in over the back of the crank, clean the interior of the sleeve with chlorinated solvent and let it dry. While the sleeve is drying, make a sleeve installation "tool." This tool is actually a 1x4 pine board about 12in long with a 1in diameter recess drilled into its center. Drill this recess about 1/4in deep so that the board fits flush against the back of the crankshaft.

To ensure that there are no oil leaks from between the sleeve and the crank, apply some Loctite Stud 'N' Bearing Mount on the crank sealing surface. You can afford to be a little generous here—any Loctite that weeps out around the sleeve can be removed with a rag.

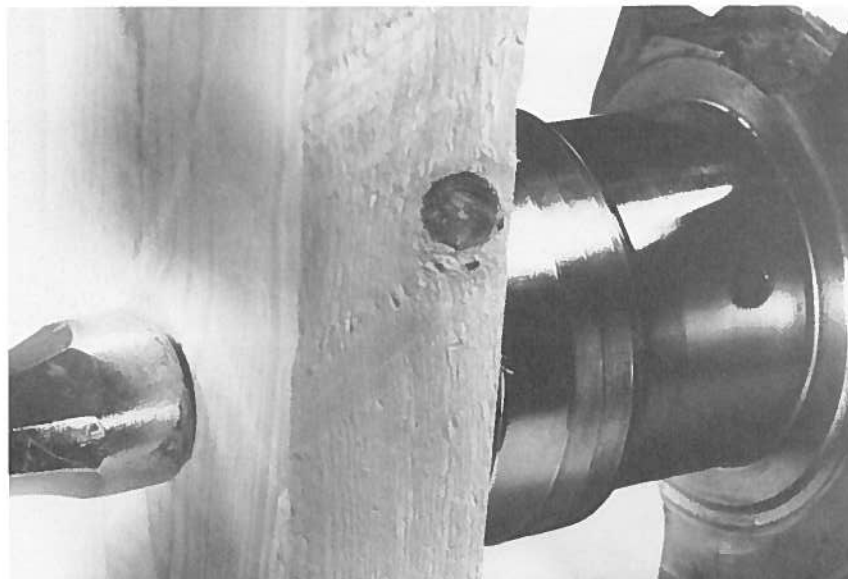
Install the sleeve by starting it on by hand. Once it's started, position the board over the back of it and gently drive the sleeve into position, using a hammer against the board. Watch your progress carefully so that the sleeve doesn't cock, and be sure that the sleeve is fully seated on the crankshaft.

Although this kit works well on crankshafts that use a 10mm seal, don't try using it on crankshafts that use a two-piece seal because the seal lips won't be able to compensate for the increase in journal diameter. This will cause them to leak after a few hours of engine operation.

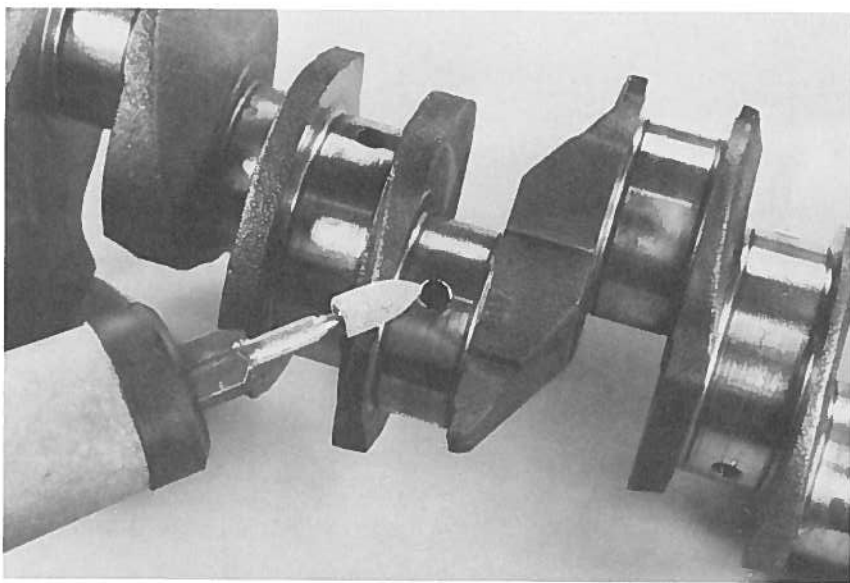
Chamfering

Before you send your crankshaft in for grinding, chamfer all the oil supply holes with a rotary grinder. Take the sharp edges off the holes and blend them so their transition into the journals is smooth. This greatly reduces the chances of the crankshaft cracking. Now is the time to chamfer the oil holes because if the grinder slips during chamfering and nicks the journal, the nick will usually be taken out during the machining process.

When you get the crank back from the shop, touch up any sharp areas once again. To reduce the chances of nicking the journals, punch a hole in a piece of masking tape that is



A hammer and a board are used to install a sleeve onto the rear of a large-journal crankshaft.



Chamfer the oil supply holes before sending the crank out for grinding.

Don't dig a hole, just break the sharp edges.

slightly larger than the hole you want to chamfer. Then place the tape over the journal and start your grinding. When you've finished grinding, remove the tape.

Pilot Bushing

If your engine is mated to a manual transmission, take a careful look at the rear end of the crank. At its center, you'll see a pilot bushing made of bronze-like material called Oillite. The pilot bushing is used to center the input shaft from the transmission. If its inside diameter is worn into an elliptical shape or is galled, it can cause the transmission to be hard to shift. Consequently, the bushing should be replaced if there's any question about its condition.

You can replace the bushing by packing the area behind it with thick grease. Then insert an old transmission input shaft into the bushing and hammer on the shaft. The hydraulic action of the grease will push the bushing out. If you don't have an old input shaft, have the machine shop replace the bushing for you. To install the bushing, carefully tap it into place, using a brass drift and a hammer.

Checking Journal Diameter

Aside from scratches and cracks, crankshaft journals can be worn undersize, tapered, out-of-round, or barrel-shaped. Even the crankshaft itself could be bent if it was mishandled

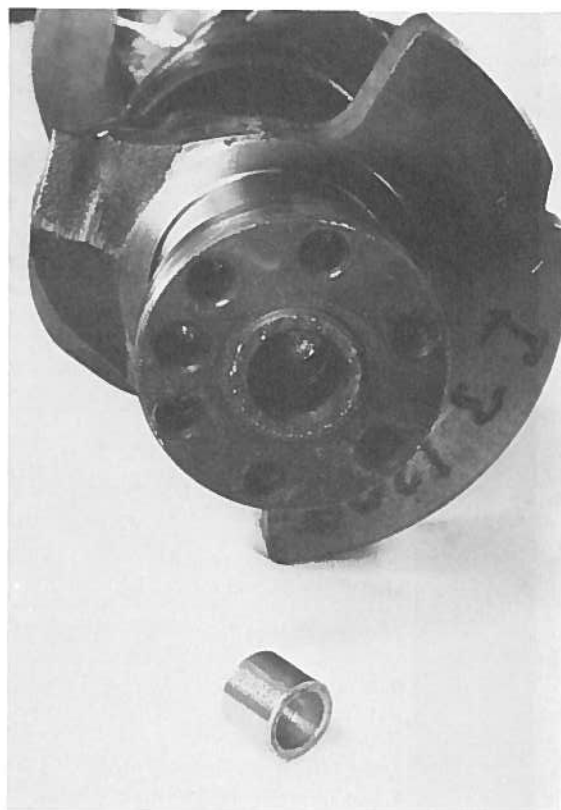
prior to installation. To check crank main journals for wear, taper, out-of-round, or a barrel shape, you'll need a 2-3in micrometer. To check the rod journals, you'll need a 1-2in micrometer.

Measure each journal in three places: near both ends and in the center, keeping the micrometer in the same plane. Then turn the micrometer 90deg and check the journal near both ends and in the center again. In all, you'll make six measurements. Record these measurements as you take them.

Compare all your measurements. If the size of the journal is below specifications, it's worn far enough to warrant grinding.

If one end of the journal is larger than the other, the journal is tapered. Taper is hard on bearings because the load of the journal is carried on one side of the bearing rather than being evenly distributed across the face of the bearing. If the journal is tapered more than 0.0005in, have the crankshaft ground.

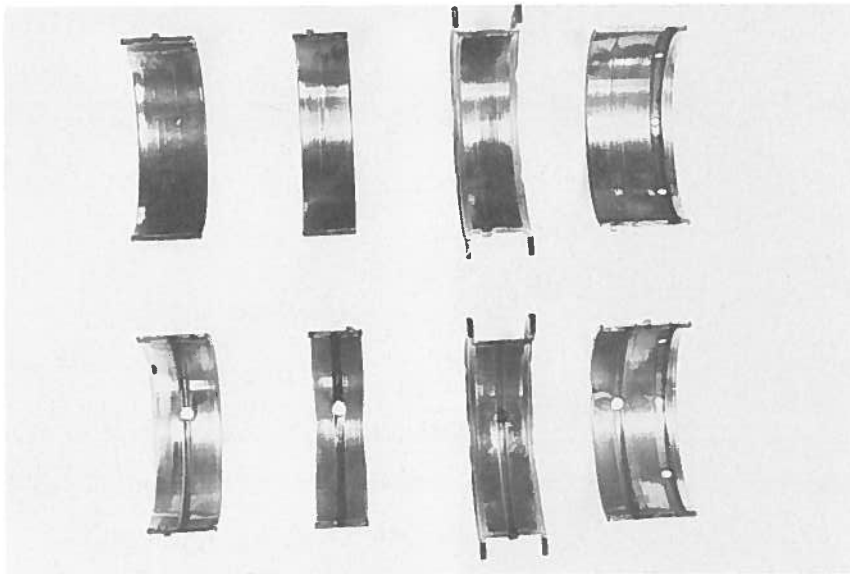
Out-of-round journals are indicated if the readings on one plane are different than they are when you turn the micrometer 90deg. Rod journals are usually afflicted with this type of wear because the piston pushes and pulls on it as the engine runs. This causes the journal to wear more in some spots than in others. If the difference between two readings taken 90deg apart is more than 0.0005in for



A pilot bushing (foreground) is used at the rear of the crankshaft when a manual transmission is used. If the transmission is hard to shift, a worn pilot bushing may be the cause.



Measure each journal for wear and taper, out-of-round, or a barrel-shape. Six measurements on each journal will give you the data you need to evaluate the crank's condition.



If the crankshaft is bent, the wear patterns on the main bearings will vary from

front to rear. You need to look at both lower and upper bearings to see this.

the main or rod journals, the crankshaft must be ground.

Barrel-shaped journals look just as you would imagine: larger in the center than at the ends. If the difference between either end and the center is greater than 0.0005in, you'll need to change machine shops. Barrel-shaped journals are caused by improper machining of the journal—nothing else. After you find a good

shop, have them grind the journals.

Checking Straightness

One clue that a crankshaft is bent is that the wear pattern on the main bearings will vary from front to rear. To see this, lay all the upper and lower main bearings out in their proper positions. If the bearings in the #2 and #3 position have the most wear, chances are the crankshaft is

bent, since crankshafts tend to bend near the middle.

An accurate way of checking for this without the benefit of a special holding fixture for the crankshaft is to turn the block upside down. Then install the upper #1 and rear main bearings into the block. Used bearings are preferred since this avoids any potential damage to the new bearings. Lightly lubricate the bearings with engine oil, then install the crank.

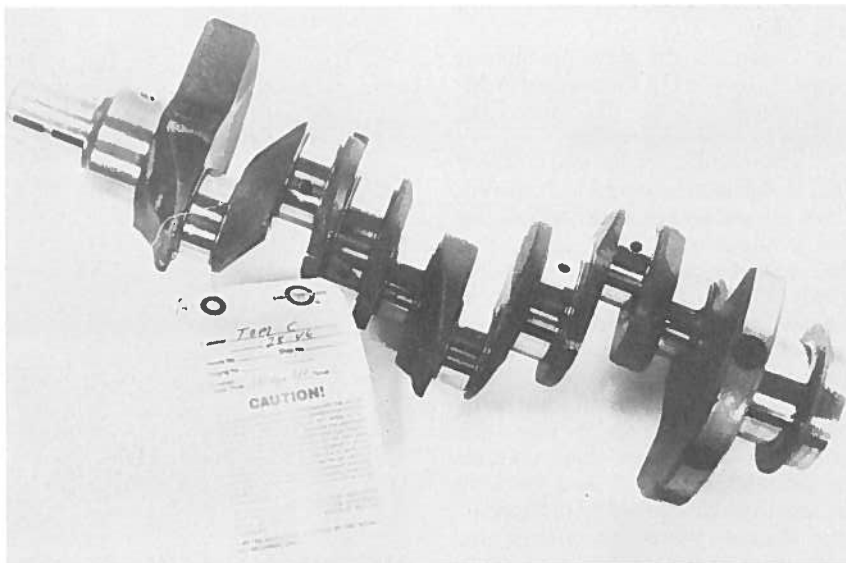
Now take a dial indicator mounted on a magnetic stand and position the tip of its spindle against the #2 main journal. Place it so that it doesn't run into the lube hole in the journal when the crank is rotated. Zero the indicator, then watch it carefully while you slowly rotate the crank. If the reading varies by more than 0.0005in, the crank is bent. If the reading is all right, move the indicator over to the #3 main journal and check it. If both readings are less than 0.0005in, the crankshaft is straight enough for use.

If your crank is bent, don't worry just yet, because a bent crankshaft can sometimes be repaired. Interestingly enough, it's straightened by loading it with a hydraulic jack and some very precisely placed blows with a hammer. But don't get out your trusty 2lb ball peen and have at it. This work is best left to someone with years of experience. A small number of shops around the country do this, including Moldex Tool in Dearborn, Michigan.

Grinding

If you have access to the factory service manual, you'll find it states that the crankshaft for the 60deg V-6 cannot be ground, only replaced. This may be true from a warranty standpoint—no one would want a reground crankshaft installed into a factory-fresh engine. However, when your engine has 120,000 miles on it and the crank journals are worn, you probably don't want to pay hundreds of dollars for a new crankshaft.

Worn but serviceable crankshafts for the 60deg V-6 can be successfully reground at a reputable machine shop or crankshaft grinding facility. Since 60deg V-6 engines tend to be "loose" when assembled, ask the machinist who's going to grind your crank to leave 0.001in "extra" on the main journals. This will help reduce oil pressure loss in the engine without being so tight that it would adversely



This externally balanced crank just returned from the machine shop. The tag on the crank gives some tips on how to minimize the chances of crankshaft fail-

ure. Make sure the grinder leaves 0.001in "extra" on the main journals to combat excessive oil pressure loss.

affect bearing life.

Crankshafts for the 60deg V-6 can be ground to two different under-sizes to correct problems: 0.25mm and 0.50mm. If the crankshaft has to be ground any more than this it'll flex like a rubber band when the engine's under a load. In this case, you'll need to junk the crank and get another.

Also keep in mind that machine shops usually grind all the main journals one size and all the rod journals one size. However, in a pinch, they can grind just one main or rod. The disadvantage to this is that by setting the machine up to grind just one journal, you've already paid about 75% of what it would cost you to have all the journals ground. After grinding, the journals need to be polished in a lathe to remove the minute peaks that remain. This is a normal part of the re-grinding process.

Checking Rod Side-Clearance

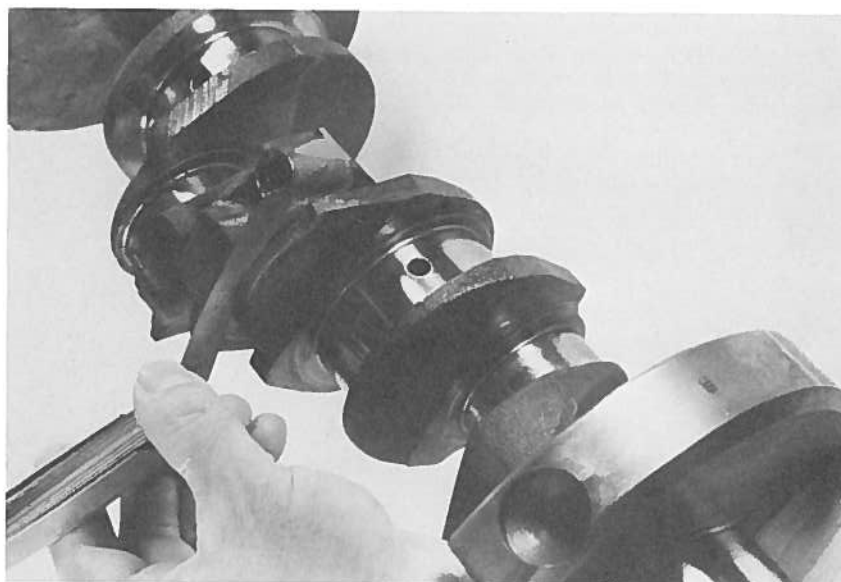
To prevent the rods from climbing up the rolled fillets on the rod journal, which could destroy the bearing, rod, and crankshaft, a certain clearance needs to be maintained between the two. This is called "rod side-clearance."

Check the crankshaft for this clearance when you pick it up from the machine shop. If the machinist who ground your crank touched the sides of the journal with the grinder, he probably took a few thousandths off—and this has a direct bearing on rod side-clearance.

To check rod side-clearance, insert the old bearings into the connecting rod cap that mates with the rod journal you're going to check. Using old bearings saves the new ones from the sliding action against the journal. Position the rod cap onto the journal, and then slide the rod cap as far as you can to one side of the journal and slip a feeler gauge in between the other side of the cap and the journal. The largest feeler gauge that fits in this gap represents rod side clearance. It should be 0.008–0.020in. If it's less than this, the side of the rod will need to be resurfaced to increase clearance. If the clearance is greater than 0.020in, the connecting rod must be replaced.

Polishing Journals

After you get your crankshaft back from the shop and have finished chamfering all its oil holes, polish the journals by hand. This smoothes any



All that's necessary to check rod side clearance is an old rod bearing, a rod cap, and a feeler gauge. Slide the cap to one side of the journal it was mated

to, then measure the clearance between the opposite side of the cap and the journal with a feeler gauge.

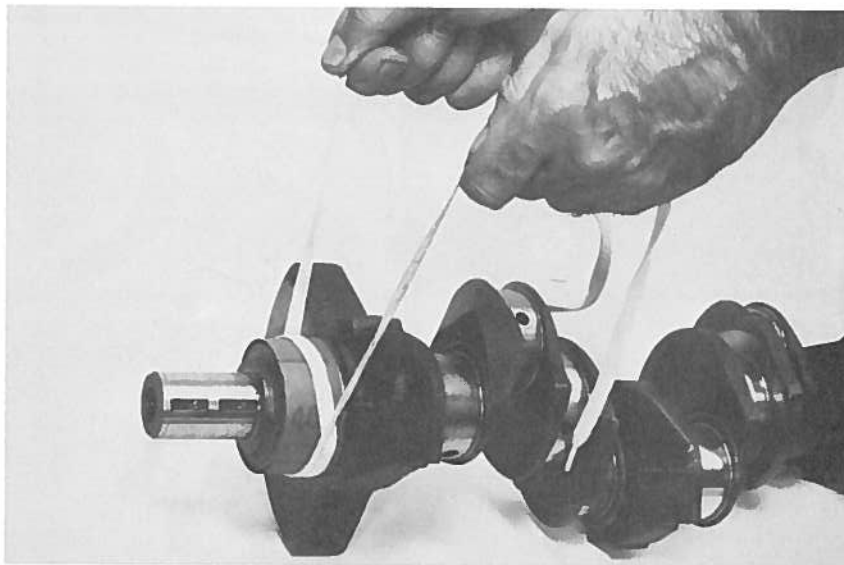
remaining surface irregularities the shop left behind, and helps maximize bearing life.

To polish the journals, cut a strip of 400-grit wet-or-dry sandpaper that's about 1/16in narrower than the journal is wide. Wrap the sandpaper around the journal, then wrap an old shoelace around the paper one-and-a-half times. Then alternate pulling on the ends of the shoelace so that the

sandpaper moves back and forth around the journal. If the sandpaper sticks to the journal, loosen the shoelace slightly. After a minute or two, the journal will be polished.

Cleaning

After all the machining and polishing operations are completed, clean the crank one last time to prepare it for installation.



A strip of 400-grit wet-or-dry sandpaper and an old shoelace are all that's needed to polish the crankshaft jour-

nals. This type of polishing helps minimize bearing wear.

Start by cleaning the lubrication holes with a snugly fitting brush from the engine brush kit. Since the sediment that collects in the holes is rather oily, use some solvent on the brush to get it out. When all the lube holes are clean, wash the entire surface of the crank with some dish soap and hot water applied with a soft brush. Be sure all the dirt and metallic debris are flushed away. To ensure that nothing remains in the oil holes, blow them out with compressed air. Dry the crank with paper towels, and then apply a light coating of engine oil or assembly lube to all the machined surfaces. If you're going to store the

crank for awhile, don't spray it with WD-40, as it tends to evaporate over a period of time, allowing the journals to rust.

When the crank is prepped, put it in a clean plastic garbage bag and store it standing straight up, out of harm's way. Incredible as it may sound, standing the crankshaft on end helps prevent it from warping.

Damper Inspection

The damper is responsible for damping the vibrations produced by the crankshaft. These vibrations manifest themselves as minute accelerations and decelerations. If left uncontrolled, the vibrations would quickly crack the crankshaft.

A damper is a ring of metal (known as an "inertia ring") that's secured to a hub on the front of the crankshaft with a rubber ring. As the crankshaft tries to accelerate or decelerate, the inertia ring on the outside of the damper temporarily lags behind, due to its rubber mounting. This action helps dampen vibration as the crankshaft accelerates or decelerates. All this working back and forth can cause the rubber between the inertia ring and the hub to fatigue and fail. To check for this, look closely at the rubber. It shouldn't be swelling out from between the inertia ring and hub. Also, sight down the damper from the top to the bottom. The inertia ring shouldn't be positioned in front of or behind the hub. If it is, the

rubber ring has failed, and the damper must be replaced.

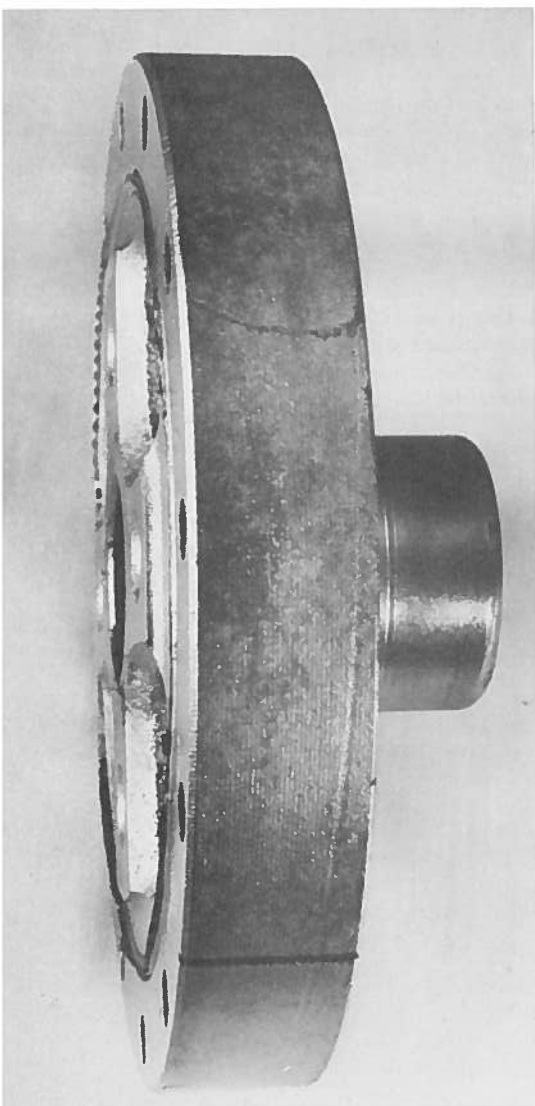
Reconditioning

If your engine has many miles on it, chances are good that the lips of the oil seal in the timing chain case have cut a groove in the damper shaft. Even if this is the case, you can still save your old damper by resleeving it.

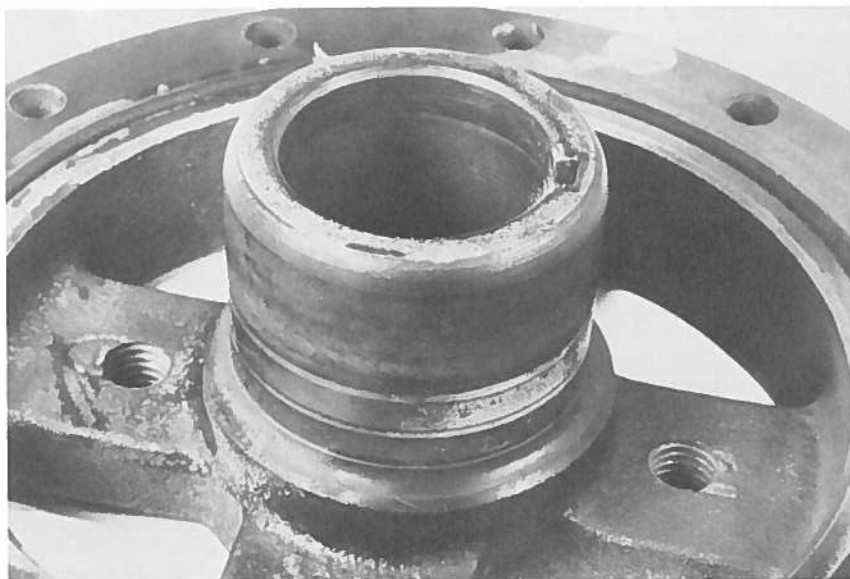
Resleeving kits are sold at many auto parts stores. They typically contain a thin metal sleeve that fits over the damper shaft and a tube of adhesive to retain the sleeve. Interestingly enough, an oversize oil seal isn't required, because the sleeve is quite thin and the standard seal can accommodate this slight increase in shaft size with no ill effects.

Prepare the damper shaft by cleaning off any gum, varnish, rust, or burrs with 400-grit or finer sandpaper. The entire surface of the shaft must be smooth and clean, or you won't be able to get the sleeve on. Clean the shaft with carb or brake cleaner to ensure that the adhesive will stick to it.

Now try to slide the sleeve over the clean shaft. It needs to fit on over the first 1/4in or so using only your hands. If it won't and you try to force it on with something else, you'll probably bend and ruin the sleeve. If you can't slip it on, the damper shaft is probably still dirty. Clean the shaft once more, then try installing the sleeve again.

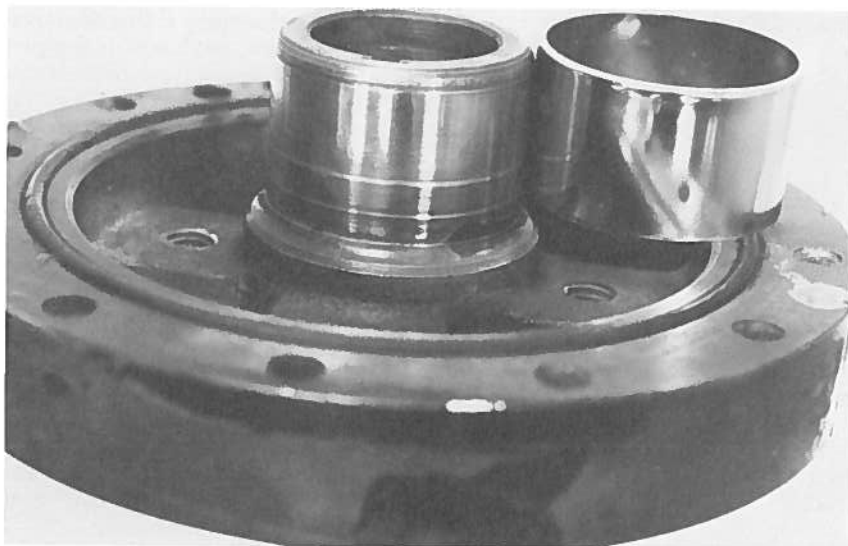


The inertia (outer) ring of the damper must be even with the hub. If it isn't, its tuning is impaired and it should be discarded. This damper is in good shape.



Believe it or not, the lips of the seal in the timing chain case can cut grooves

in the damper neck. This problem can be remedied with a sleeving kit.



When installing the sleeve, it's important that it be fully seated on the neck of the damper. To know when it's fully seated, hold the sleeve next to the neck and then mark where the sleeve ends.

The sleeve should meet this mark when it's fully installed. After the sleeve is started, tap it onto the damper using a 2x4 and hammer as shown. If you cock the sleeve, you may have to scrap it.



The wear pattern on the circumferential grooves of the pistons can give you a rough idea of piston and cylinder wear. After 160,000 miles, the circumferential grooves on this piston are hardly worn!

When you can install the sleeve over the first 1/4in of the shaft, remove it, and clean its inside and the outside of the damper shaft with brake cleaner. Now apply a thin coat of the supplied adhesive to the entire surface of the shaft, then slip the sleeve on as far as it will go. You don't need to hurry, because the adhesive is anaerobic which means it won't cure until the sleeve is on.

With the damper on a hard surface, position a short length of 2x4 over the end of the sleeve, and tap the sleeve on with a hammer. Use several light blows as they're less likely to cock the sleeve on the shaft than one or two heavy ones. If the sleeve cocks, it may bend—and the timing case seal won't seal against a bent sleeve.

When the sleeve bottoms out on the damper, clean off any visible adhesive with a rag. Now your damper is as good as new.

Pistons

The pistons used in all the 60deg V-6 engines are basically the same except for sizes. However, there is a difference between the pistons used in engines with cast-iron heads versus those used in aluminum-head engines, and that is piston dome design. Whereas the pistons used with cast-iron heads are flat-topped, pistons used with aluminum heads are dished. When combined with the

valve angle and combustion chamber shape in the aluminum heads, these pistons help increase the turbulence of the incoming air/fuel charge, resulting in fewer emissions and potentially more power.

Factory pistons have grooves that run around the circumference of the piston skirt. These grooves help retain oil, which reduces wear of both the piston and cylinder bore. Usually, as the piston wears against the bore, these circumferential grooves fade. The degree and pattern of wear on these grooves can give you a general idea of how worn the piston and cylinder are and whether they need to be serviced.

If only five or six of these grooves closest to the top of the skirt are worn, and their worn area is only 1/2in wide or so, it's a good bet that the piston and its mating cylinder are in good shape. Alternately, if one-third or more of the grooves are worn, and the worn area is greater than 1-1/4in wide, the piston is probably shot and the cylinder could probably stand to be rebored as well.

Checking Piston-to-Bore Clearance

The clearance between the piston skirt and cylinder bore must be sufficient to avoid piston scuffing. Scuffing is caused by the piston repeatedly contacting the cylinder wall.

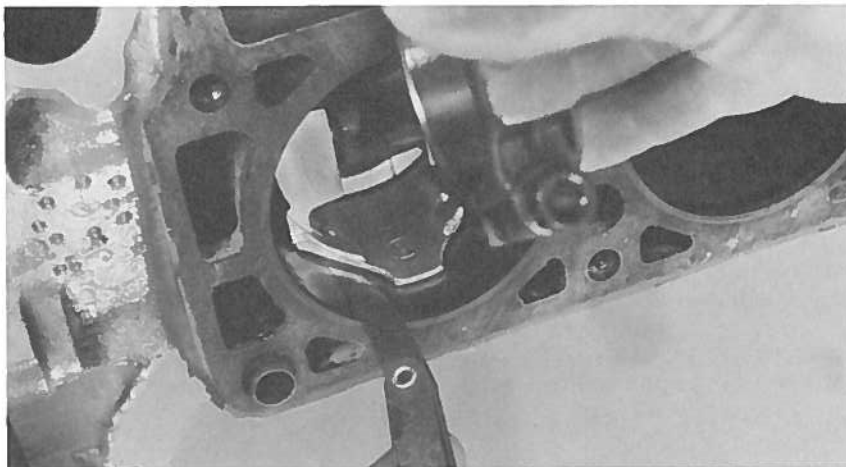
When this happens, minute surface irregularities temporarily weld themselves together. As the piston moves further in the cylinder, these welds are torn apart, resulting in transfer of metal from one surface to the other. Scuffed pistons indicate insufficient clearance between the piston and cylinder bore, overheating, lugging, or insufficient lubrication.

On the other hand, if piston-to-bore clearance is too large, the piston can rock side-to-side in the cylinder, causing piston "slap." Piston slap prevents the rings from squarely contacting the cylinder, diminishing their sealing capabilities causing excessive blow-by, oil consumption, and loss of compression.

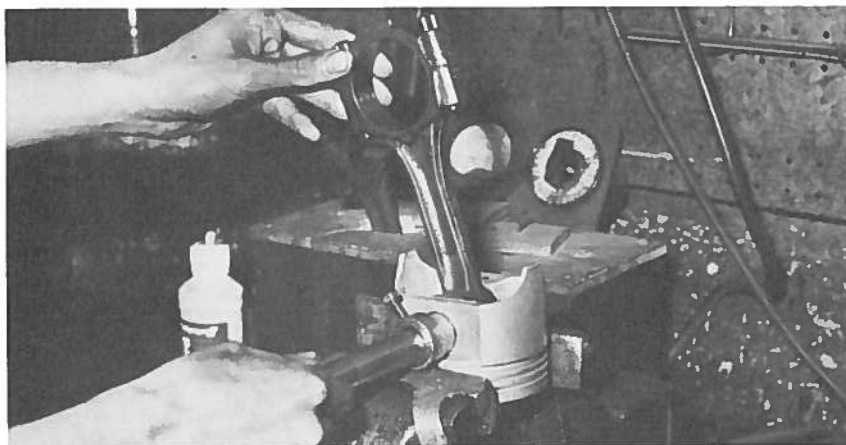
There are basically two ways of economically measuring piston-to-bore clearance: a feeler gauge or a 3-4in micrometer and telescoping gauge (the more accurate of the two).

Feeler Gauge Method

To check piston-to-bore clearance using a feeler gauge, insert the piston—minus its rings—upside down in its cylinder. Make sure the piston pin is parallel to the crankshaft's length and that the piston skirt is about 1/2in below the top of the cylinder. Then measure the clearance between the skirt and cylinder with a feeler gauge. The largest gauge that fits in with a light push represents pis-

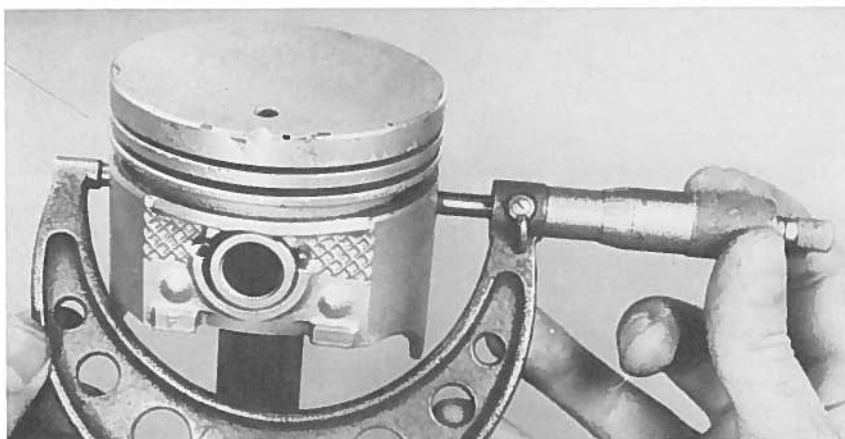


Piston-to-bore clearance is critical to engine life: too tight and the pistons scuff, too loose and you'll hear piston slap.



Although the pins are a press-fit, they can be installed by hand after the small end of the rod is heated. As soon as the

rod begins to cool, the pin is locked into the rod. The autoclave behind the piston is used for heating the rods.



Since the largest diameter of the piston is at a 90deg angle to the piston pin bore when the piston is at room tem-

perature, take your piston measurement here.

ton-to-bore clearance. If this clearance exceeds 0.002in, you'll need a new piston, and you might have to have the cylinder bored. Refer to the following "Remedies for Excessive Clearance" for more information.

Micrometer Method

A fairly accurate way to check piston-to-bore clearance is with a 3-4in micrometer and a telescoping gauge. To use this method, first measure the diameter of the piston at the centerline of the piston pin, but 90deg away from the pin. Write this figure down. Next, measure the diameter of the cylinder with the telescoping gauge. Position the gauge about 1in below the top of the cylinder, at a right angle to the crankshaft.

Now measure the gauge and subtract the piston size from the gauge size. The result is piston-to-bore clearance. If this indicated clearance is around 0.0013in, you're in the middle of the factory specs, and you can keep your old pistons in service, provided their ring grooves (known as ring lands), skirts, and pins are in decent shape.

Remedies for Excessive Clearance

If indicated clearance was 0.002-0.0025in and your cylinders have never been bored oversize, you could use the service pistons available from your local GM dealer. Because these pistons are only 0.001in oversize, the cylinders retain as much metal as possible after a light honing. Unfortunately, they're also more expensive than aftermarket pistons. On the other hand, you can replace just one piston without affecting engine balance.

If the cylinders are worn more than 0.0025in, they need to be honed to the next oversize. Unless you're really broke, this is the option you should take, since you've already spent a considerable amount of time removing the engine anyway. And don't forget to order the appropriately sized pistons and rings for your freshly honed cylinders. Your machine shop can install new pistons on your old rods.

Ring Grooves

The condition of the piston's ring grooves and the clearance between the rings and the grooves are both important. If the rings are allowed to rock excessively in the ring groove, they won't be able to seal the

cylinder properly, resulting in a decrease in power and an increase in oil consumption.

Check the condition of the ring grooves by looking at them while rotating the piston in your hands. They should be straight and flat, allowing the rings to rotate freely. If they're bent, the piston has been mishandled and should be scrapped if it's old. However, if you just bought the pistons and you didn't bend the grooves, bring them back to the store and explain the situation. A reputable shop that wants your future business will exchange the piston.

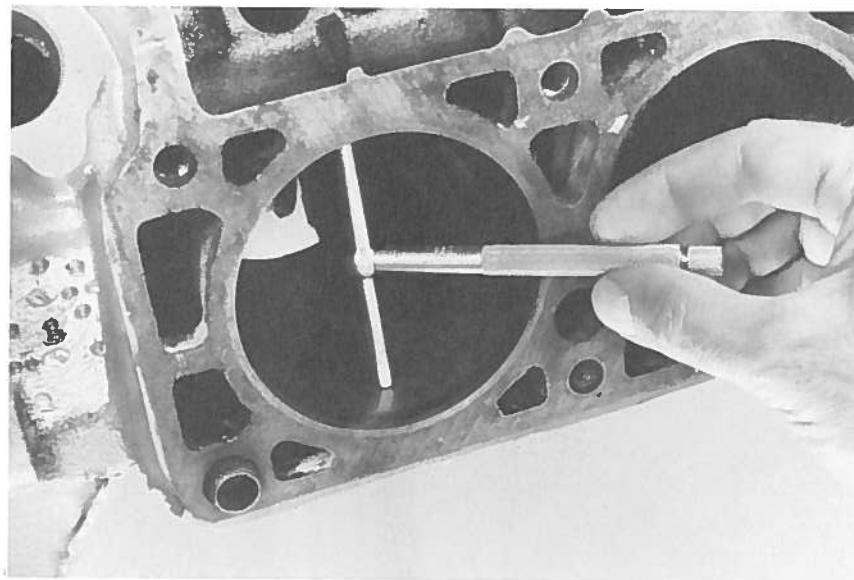
Bell-mouthed ring grooves present another problem that only happens on used pistons and is usually caused by excessive ring side-clearance. Damage of this sort can sometimes be corrected by widening the ring groove in a lathe and then using a spacer to take up the excessive clearance. However, since this operation is more of a band-aid than a real fix, you should replace the piston.

Checking Ring Side-Clearance

The clearance between the sides of the piston rings and the ring grooves is also important. If clearance is too great, the rings won't be able to stay square to the cylinder because they'll be rocking up and down in the ring grooves. This results in poor ring sealing, which, in turn, reduces power and fuel economy. On the other hand, if clearance is insufficient, the rings won't be able to rotate as they should.

You can measure ring side-clearance with a set of feeler gauges. If you have new pistons and rings, simply slide the largest feeler gauge you can between the side of the ring and the land. To ensure that this clearance is the same all around the piston, check around the entire groove. Information on ring side-clearances can be found in the Specifications section at the rear of this book.

You can use this same technique to measure used rings on used pistons, but there's a twist because if side clearance is excessive, you won't know whether the rings or the piston needs to be replaced. To distinguish between the two, measure the thickness of the old ring with a micrometer, then subtract this dimension from the size of a new ring (refer to the Specifications section). Add this difference to the side clearance specification. This "adjusted" clearance indi-



Since the cylinder bore wears the most at the top (and bottom) of the ring travel, take your measurement there.

cates the maximum gap between the ring and ring groove. If your measured clearance is greater than the adjusted clearance, the piston ring grooves are too wide. Although this gap can be adjusted by cutting the ring groove in a lathe and installing a flat metal spacer between the ring and ring groove, don't do it unless you're very short on funds. This "patch" probably isn't worth the money you'll spend on it. Instead, you're better off buying a new set of pistons and rings, along with a rebore.

Adjusting Ring End-Gap

A piston ring's end-gap allows for thermal expansion of the ring when it's at operating temperature. If end-gap is too small, the ends of the ring will butt against each other before the ring has completely expanded. Since the ring can't expand into the end-gap, to expand further, it must push outward. This additional pressure causes the ring to scuff the cylinder, creating extra friction and wear. On the other hand, excessive piston ring end-gap allows combustion pressure to blow down the cylinder into the crankcase. And with this pressure comes raw fuel, carbon particles, and other contaminants.

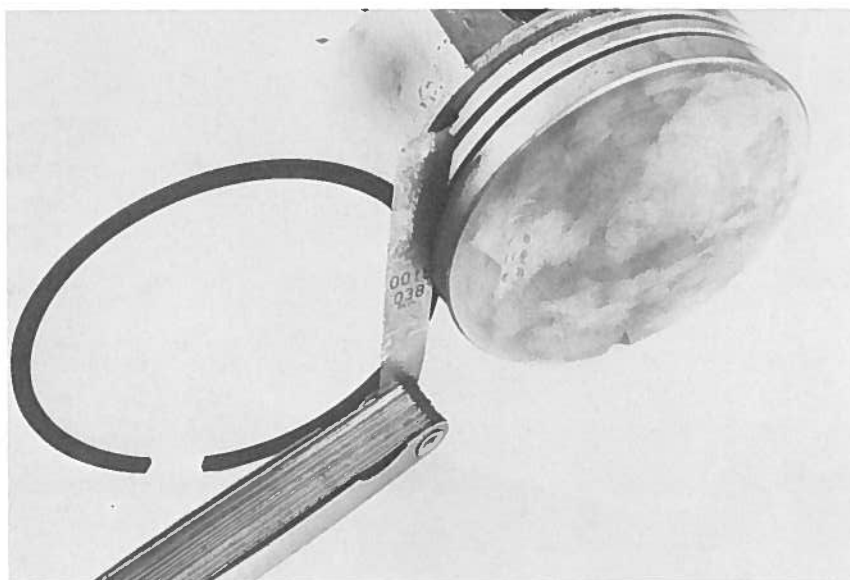
Clearly, proper piston ring end-gap is critical for several reasons, so you need to check it and adjust it if necessary. This process varies somewhat depending on whether the cylin-

ders have been freshly rebored. If they have, they're the same diameter from top to bottom, so you can measure ring end-gap with the ring positioned anywhere in the cylinder.

However, the story changes with used bores. The pressure generated by the combustion process tends to push the rings tightly outward against the cylinder, causing the cylinder to wear.



The clearance between the rings and the grooves they nest in (called the ring lands) is critical to power production and oil consumption.



The rings don't need to be installed to check side clearance. Simply use the edge of the ring and a feeler gauge to

measure the clearance around the entire perimeter of the piston.

This effect is most pronounced at the top of the cylinder and diminishes as the piston moves down the cylinder, because the combustion pressure drops markedly as cylinder volume increases. Hence, cylinder wear is greatest at the top and the least at the bottom. When you have to choose between too much and too little end-gap, err on the side of too much end-gap, so that the rings don't scuff the cylinder.

Consequently, position the rings in the bottom of the cylinder with the least amount of wear (the bottom) so that measured end-gap will be at its smallest.

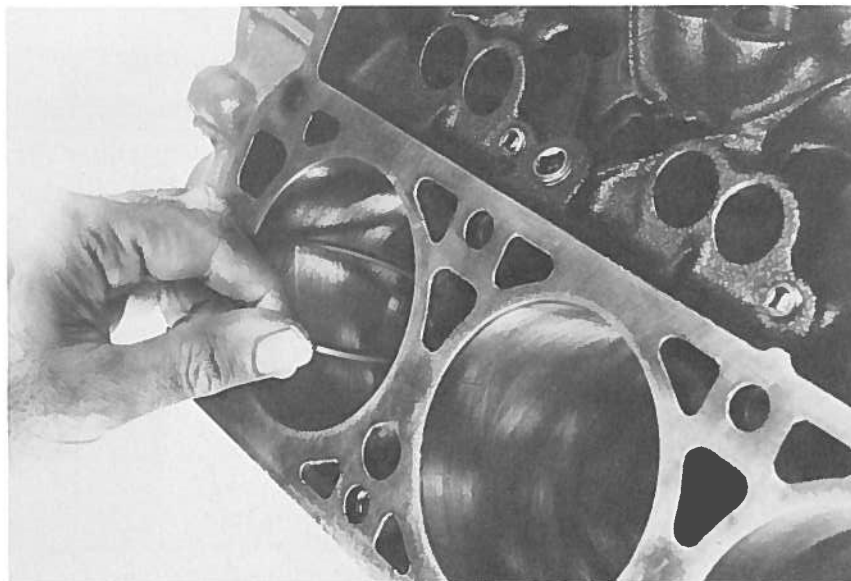
So if you're measuring end-gap in a used cylinder, place the ring about 1/2in away from the bottom and square it in the bore with a piston. The ring must be square in the bore to measure ring end-gap accurately. If

the cylinder has been freshly bored, position the ring about 3/4in down the bore, and use a flat-top piston to square it to the bore. Now insert a thin feeler gauge into the end-gap and continue inserting the next-thicker gauge until one won't fit.

Compare this reading with the specifications listed at the end of the book. If it's less than specifications, you'll have to increase the end-gap by filing the ends of the ring. To do that, take the ring out of the bore and position it in a soft-jawed vise. If your vise doesn't have soft jaws, slip two 1x6 boards into the jaws, then place the ring between the boards.

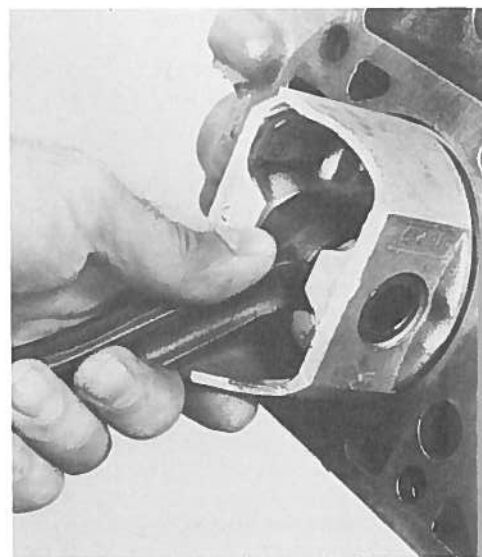
With the end-gap just peeking out over the vise jaws, file it with a fine-toothed, flat file. File from the outside of the ring in, to prevent chipping the wear surface of the ring. Be sure to file the ring evenly, and recheck the end-gap frequently so that you don't open it up too far.

If the measured ring end-gap is too large, you will have to get another set of rings. Ring end-gaps for the exact same cylinder bore dimension can vary between piston ring manufacturers, so you'll want to trade your rings in (if you bought them new) for another brand. This is when buying



To minimize the chances of scratching the cylinder with the ring, compress it slightly with your hand and push it into

the bore as shown. When it's in the bore, you can spin it 90deg so that its wear surface is flat against the bore.



Square the ring to the bore with a flat-top piston. If the bore is used, the ring should be positioned at the bottom of ring travel, about 1/2in from the bottom of the bore. On freshly bored cylinders like these, the ring can be positioned anywhere. However, to make your work easier, position the ring about 3/4in down the bore.

your engine components locally pays off, because reputable shops will allow you to try another ring set from a different manufacturer. Some mail-order stores will also let you do this, but, of course, more time will be required.

As you prepare the ring end-gaps, keep in mind that because of the possible variations among cylinders due to machining or wear, ring end-gaps are specific to each cylinder. Therefore, you need to designate a certain set of compression rings and oil rails for a particular cylinder, measure them in that cylinder, and keep them specifically for the piston that fits in that cylinder.

Piston Pin Bore

The piston pins in all 60deg V-6 engines are pressed into the connecting rods. In turn, the pins are housed in the piston pin bores. To check the wear of the piston pin bore, all oil must be eliminated from between the pin and the bore. Do this by either immersing the piston in a pan of solvent while moving the connecting rod back and forth or by spraying the area between the pin and bore with brake cleaner.

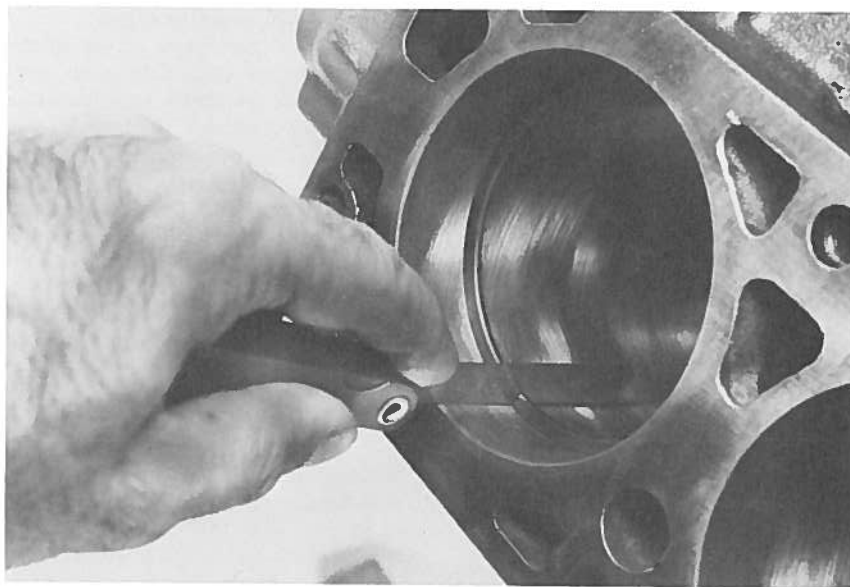
When you're sure no oil exists between the pin and bore, check for play by holding the head of the piston against the top of the bench and lightly touching the pin with your thumb and forefinger. Use your other hand to hold the end of the connecting rod, and rock it side-to-side towards the ends of the pin while you feel for pin movement with your thumb and forefinger. Next, try twisting the rod in a circular motion while again feeling for any pin movement. If you feel the pin move at all while performing either of these two tests, the pin bore is shot.

Although a piston with this type of damage can be salvaged by honing it (and its mating connecting rod) for an oversize piston pin, the cost of this work isn't that far from purchasing a new piston.

Connecting Rods

The forged and heat-treated connecting rods used in the 60deg V-6 engines have proven to be trouble-free in regular and limited high-performance use. Consequently, your rods are probably in good condition. Still, you should check them to be sure.

Each rod has what is referred to as a "big" end and a "small" end. The big end of the connecting rod wraps



With the ring square in the bore, you can measure end-gap. The largest

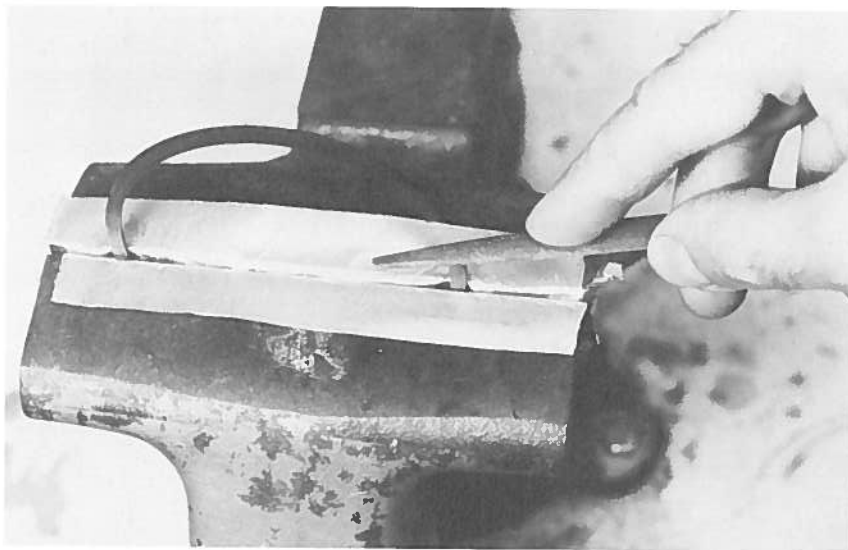
feeler gauge that fits in between the ends of the ring represents end-gap.

around the rod journal, and the small end houses the piston pin. As the miles pass, the constant up-and-down motion of the piston and crankshaft can make these bores become egg-shaped from top to bottom. Check for this type of wear with a micrometer and snap gauges.

Check the rod's big end in three places: directly in line with the beam of the rod and about 45deg on either side of it. If the reading in one direction is greater than the others by

more than 0.0005in, the big end of the rod needs to be reconditioned. This is accomplished at a machine shop by milling a small amount of metal off the mating surfaces of the cap and rod, then bolting the cap onto the rod and passing a hone through the rod.

The small end of the rod should be checked in two places: in a direction parallel to the beam and 90deg to it. If the difference between the two readings is greater than 0.0003in, the bore needs to be honed and a larger-

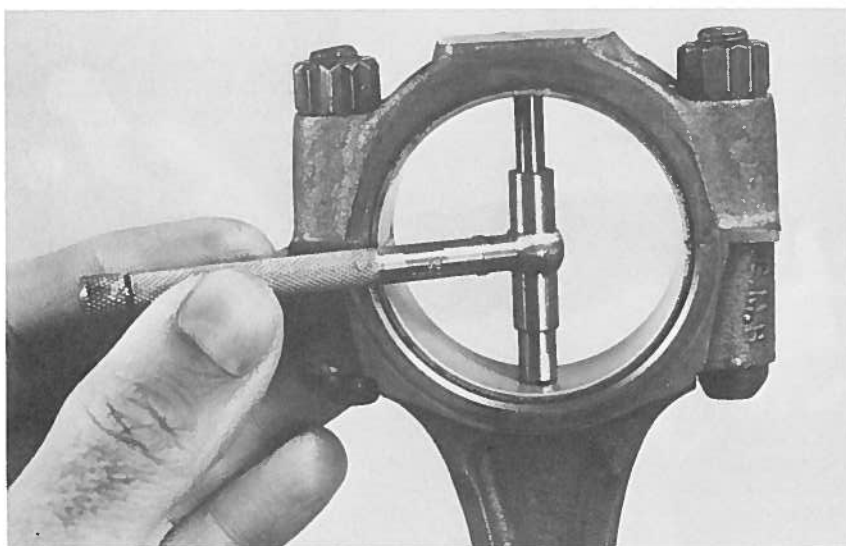


To adjust end-gap, put the ring in a soft-jawed vise as shown. File the ring from the outside in to prevent chipping the

outer surface of the ring. When end-gap is set, lightly chamfer the edges of the ring where you just filed.



You can gauge wear of the piston pin bore by holding the piston as shown and trying to rock the connecting rod side-to-side and in a circular motion. If you feel any movement, the piston pin bore is shot.



The big end of the rod (shown here) should be checked in three places with a snap gauge and micrometer. If one

diameter piston pin installed.

If you don't have access to micrometers and snap gauges or don't know how to use them, your local machine shop can check the rods for you for a small fee. As a matter of fact, in most cases it's preferable that your machine shop check them since minor differences in wear have a major impact on bearing life. Machine shops have a rod gauge that can accurately measure variations in the rods and will be able to handle them accordingly.

Checking for Twist and Bend

Although it happens rarely, connecting rods can twist and/or bend. The biggest clue that a rod is twisted or bent is that the upper and lower halves of the rod bearing will be worn on opposite sides. Another clue is piston wear that is high on one side and low on the opposite side. Refer to the "Engine Bearings" sidebar in Chapter 5 for more information.

If you find signs of twisting or bending, show your local machinist the piston assembly in question and ask for his opinion. In most cases he'll probably advise you to scrap the rod.

Rod Bolt Removal and Replacement

If the threads on a rod bolt are damaged, the bolt must be replaced. To do this, clamp the big end of the rod in a soft-jawed vise so that the threads of the bolt are pointing up-

ward. Then carefully tap the bolt out with a brass drift and a hammer.

To install the new rod bolt, slip it into the rod so that the flat side of its head will mate with the flat on the rod. Then carefully drive in the bolt, using a brass drift and a hammer. The underside of the bolt head must be flat against the bolt seat on the rod so that the rod nut doesn't loosen.

Camshaft

As most hot-rodders know, the camshaft of an engine is one of the major determinants of power. It also helps determine how smoothly the engine operates. Conversely, the power an engine produces, and its smoothness, can tell you something about the condition of a camshaft.

If engine power is sufficient, and the engine runs smoothly with no valvetrain clatter, the cam is probably in good shape. However, if power is low, the engine runs roughly, or the valvetrain is extremely noisy, look at the camshaft. It makes sense to check the condition of the cam first, because if you need a new cam, you're going to need new lifters also.

High-Performance Tip: Connecting Rod Preparation

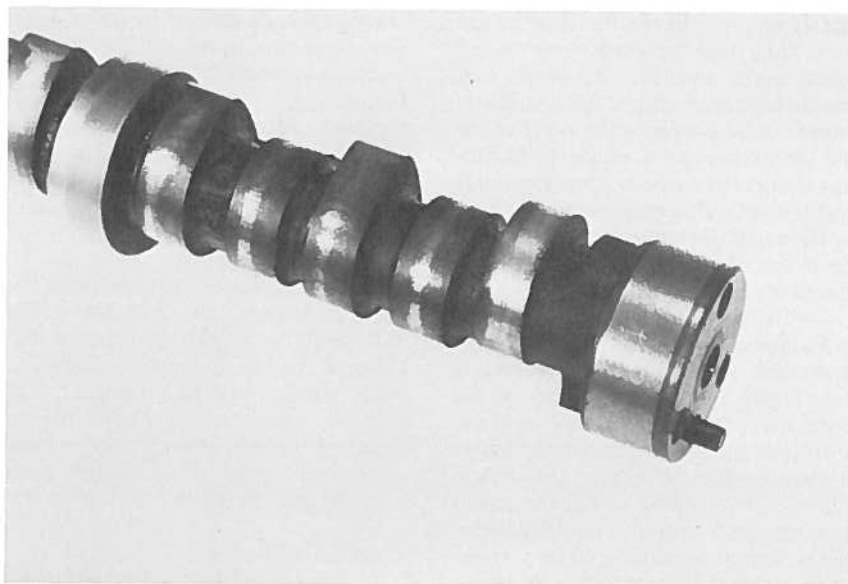
The connecting rods in the 60deg V-6 are pretty tough items in stock form. However, if you want to upgrade their strength, you can take the route of Magnafluxing, polishing, and shotpeening them.

Magnafluxing is always done before polishing and shot peening. After all, why take the time and expense of polishing and shot peening if the rod already has a crack in it? Cracked rods should be relegated to the scrap bin.

Connecting rods are polished to relieve the surface tensions in the metal and to remove any fragments that may act as crack-causing stress risers. The polishing process usually entails using a die grinder outfitted with an abrasive cartridge of 150- to 180-grit. The object here is to grind off all the forging marks without removing any metal from the rod itself. To prevent rod failure, the beam should always be polished in a direction parallel to it.

Shot peening is the last step in the process. As its name implies, shot peening is the process of peening a surface with very small round balls of metal called "shot." The shot actually compresses the surface of the rod, helping to prevent stress cracks from developing.

dimension is larger than the other two by more than 0.0005in, the rod needs to be reconditioned.



Cam lobes take a lot of abuse, so check them carefully. Lobes that are flatter than the others or are pitted indicate that the camshaft and lifters must be replaced. The lobes on this cam are shiny

on less than half their surface, which means the lobes are in decent shape. If more than half the surface of any lobe is shiny, the cam is trash can material.

First check the lobes. The noses of the lobes—that is, the highest point on the lobes—should all have the same amount of radius. Each lobe is tapered about 0.001in across its face, which causes the lifter to rotate, preventing rapid wear of the lifter and lobe. So if a lobe is in decent condition, less than one-half of the side of each cam lobe will be worn. Worn areas are shinier than areas that aren't worn. If more than half the lobe is shiny, it has lost its hardness and will wear rapidly. If any lobe on your camshaft fits this description, pitch it. Also look for signs of pitting. Deep pitting means that the cam (and lifters) should be replaced.

One of the most important factors of a camshaft is the height of each camshaft lobe. If the lobes are lower than what they should be, engine power will be down. Check camshaft lobe height by following the procedure outlined in Chapter 2. If you've already found that one or more of the lobes are worn beyond specifications, get a new cam and lifters. Remember, never use old lifters on a new cam because they'll destroy the cam in a matter of minutes.

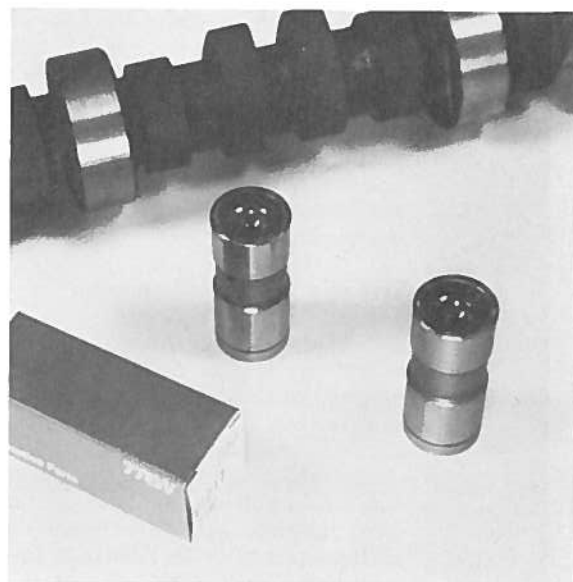
Now measure the diameter of the camshaft bearing journals, using a micrometer. If they're smaller than 1.867in, you'll need to replace the cam. Although this rarely happens

because the cam bearings almost always wear before the journals, if the journals are undersize, the engine will lose oil pressure. The amount of pressure lost is directly proportional to how small the journal is. If it's undersize by 0.001in or so, pressure loss will be small. On the other hand, if the journal is undersize by 0.005in, oil pressure will be incredibly low.

Lifters

If the cam passes inspection, check the lifters, but don't waste your time if your cam is shot, because you'll need a new set of lifters anyway. As explained earlier, you shouldn't use new lifters on an old cam because a lifter and cam lobe wear into very specific mated patterns that cannot be duplicated and if you change one or the other, the wear pattern in the "old" component will wear the new component down. This is especially true because of the high unit loading between the lifter foot and cam lobe. However you can install a used cam with used lifters if the lifters are matched to the lobes onto which they were originally positioned, the cam lobes are in good shape, and the lifters still have some crown to them.

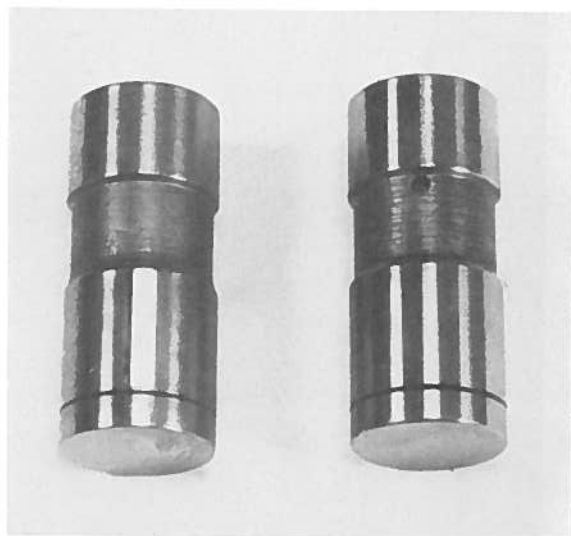
You can check for lifter crown by placing the feet of two lifters against each other and then trying to rock them. If there's any crown left, you



If you're going to spend money on a new cam, always get a new set of lifters to go with it. Using worn lifters on a new cam means almost instantaneous destruction of the cam.

should feel them rock slightly. If they don't rock, they're trash can material.

If you have to purchase new lifters, make sure they have a flat section on their lower half. This flat is es-



The bright spot at the lower portion of the lifter on the left is essential to the lubrication of the lifter foot and cam lobe. Don't use any lifters without this flat. The hole in the lifter on the right allows oil to flow from the block into the lifter. Your lifters should have both of these features.

sential for lubrication of the base of the lifters as well as the cam lobes. If you try using a lifter without this flat section, the lifter and the cam lobe it rides against will live a life measured in minutes. To make the new lifters more compatible with the cam, polish their feet with 600-grit wet-or-dry sandpaper.

Timing Chain Components Timing Chain and Gears

With all the acceleration and deceleration of the crankshaft and camshaft as the engine works year in and year out, it's no wonder the timing chain and gears wear. The acceleration and deceleration of the cam and crank pull on one side of the chain, then the other. After hundreds of thousands of cycles like this, the chain begins to stretch.

If the stretching gets severe enough, the chain can "jump" on the sprockets, causing the engine to run

poorly or, more likely, die. And an engine that has "jumped time" won't start again until the camshaft and crankshaft are brought back into the proper relationship with each other via the timing chain. Slack in the timing chain also wears out the camshaft and crankshaft sprockets as the chain is snatched one way, then the other. So if the timing chain is bad, so are the cam and crank sprockets.

To check the timing chain, grab it at the midpoint between the cam and crank sprockets and try moving it side-to-side. If total side-to-side movement exceeds 1/4in, the chain and the sprockets must be replaced. However, it's always best to replace the timing chain and sprockets whenever you're rebuilding an engine. This eliminates the potential for timing chain trouble in the near future—trouble, in many cases, that requires engine removal.

Timing Chain Damper

The timing chain damper dampens the free play in the timing chain by restricting the side-to-side movement of the chain. In turn, this increases the life of the timing chain. However, as the miles pass, the chain eventually becomes looser.

If the chain gets loose enough, it can cut grooves into the damper. Shallow grooves really won't degrade the effectiveness of the damper, but if

the grooves are more than about 1/8in deep, you should replace the damper because it won't be able to dampen the oscillations of the timing chain effectively. You should also replace the damper if its rubber coating has become hardened, or if the rubber is cracked or has chunks missing.

Cylinder Heads

Two different cylinder head designs have been used with the 60deg V-6 family: cast-iron with intake and exhaust valves that are parallel to each other, and aluminum with splayed intake and exhaust valves. Splayed valves, are valves whose stems are splayed out rather than parallel to each other.

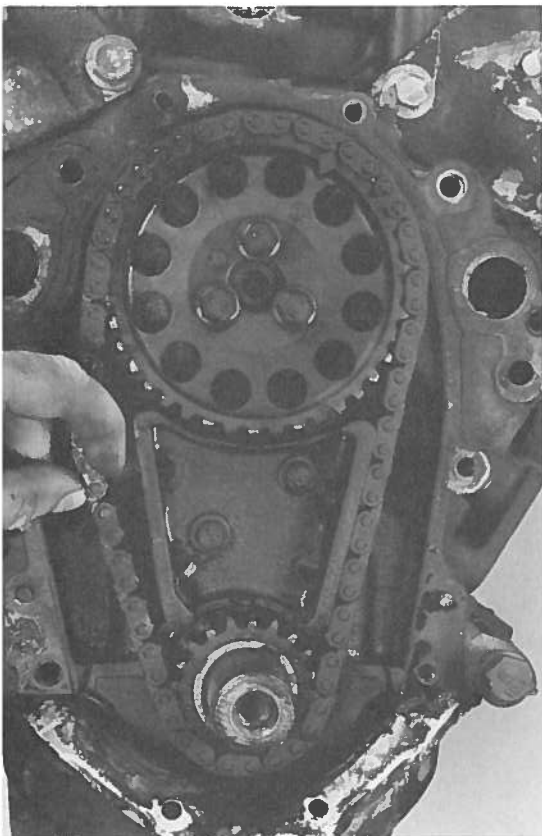
Cast-Iron Heads

Cast-iron heads were used on all 1980–1986 engines fitted to front-wheel-drive cars and on all engines installed on 1982–1993 rear-wheel-drive vehicles.

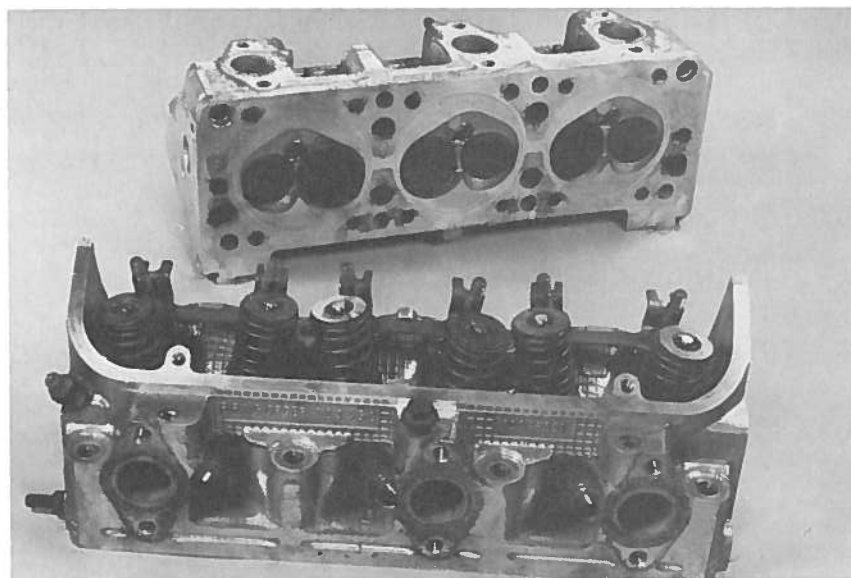
Standard cast-iron heads are equipped with 1.60in-diameter intake valves and 1.30in-diameter exhaust valves. High-output and fuel injected versions of the cast-iron heads are outfitted with larger-diameter 1.72in intake and 1.42in exhaust valves.

Aluminum Heads

The 1987 model year heralded



A loose timing chain can actually "jump" over the teeth of the sprockets, necessitating a partial teardown of the engine. The timing chain (and gears) should be replaced if side-to-side play exceeds 1/4in.



Splayed-valve heads are so named because the valve stems of each pair of intake and exhaust valves are canted or "splayed" away from each other. These heads have only been used on

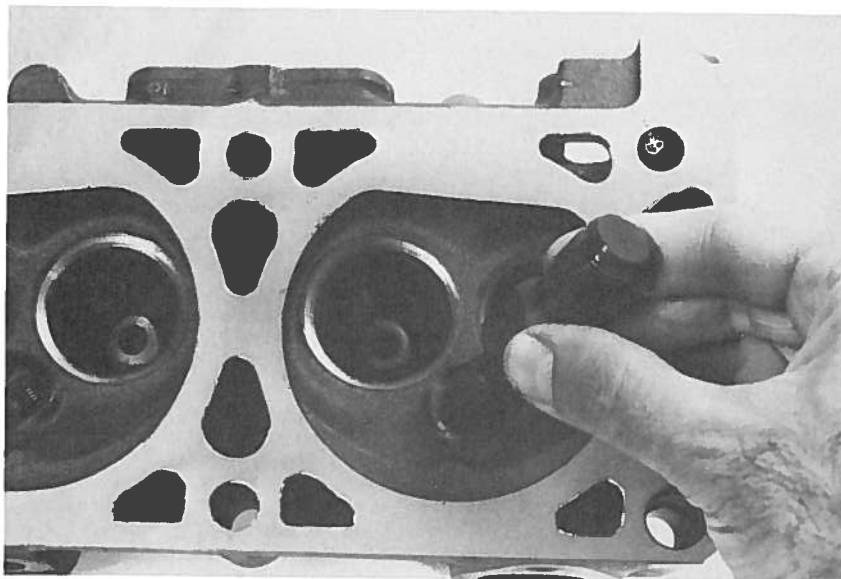
front-wheel-drive cars and provide the most performance potential. Note the 28cc heart-shaped combustion chambers that must be used with dished pistons to prevent detonation, even at idle.

High-Performance Tip: Cylinder Heads

The good news for hot-rodders is that the only difference between the small valve heads and the large valve heads is the size of the valves. The intake ports, exhaust ports, and combustion chamber are identical in both heads. So, provided you can get more air and fuel into the engine via a hotter cam, readjusted carburetor, altered PROM, and some other tricks, you'll get more power out of the larger valves.

Also, both of these cylinder heads feature a "vane" in the bottom of the intake ports. Contrary to what you might think, this little appendage increases air flow through the port, so don't be tempted to remove it to increase air flow.

If you're really serious about producing power, your engine should be outfitted with the aluminum, splayed valve heads. Due to the position of the valves and the shape of the combustion chambers, these heads offer a substantial increase in power over the parallel valve heads. However, to use these heads, you'll need a myriad of related parts designed specifically for this engine, including dish pistons, an intake manifold, thicker head gasket (0.065in versus 0.045in), head gasket bolts, pushrods, valve covers, and related gaskets. It's a costly proposition to make the change to splayed-valve heads relative to the extra power they'll give you, but it's the best way to go if you're really serious about getting that "extra" edge.



Cleaning the spark plug threads with a chase prevents grit from the threads from falling into the cylinder when you screw the spark plugs in, and produces a truer spark plug torque reading. After

this head was decked, all the sharp edges around the coolant passages, bolt holes, and combustion chambers were removed to inhibit crack formation.

possibly some commercial gasket removers such as those offered by Permatex. To clean debris off cast-iron heads, use a flat steel gasket scraper. Hold the blade flat against the head and scrape off the debris. Take care

not to use the edge of the blade, as it can gouge the metal.

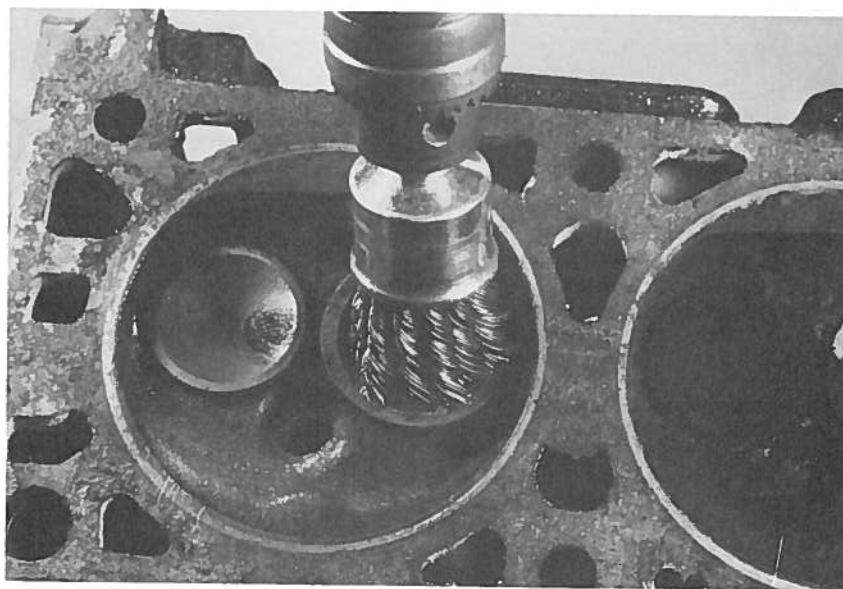
Cleaning aluminum heads takes more care and patience than cast-iron heads. To avoid gouging them, use a nylon scraper to remove

the introduction of the "Generation II" aluminum heads on front-wheel-drive cars. These cylinder heads feature 1.72in intake valves and 1.42in exhaust valves that are tilted (splayed) toward the center of the combustion chamber. The idea here is to move the valves away from the side of the combustion chamber as valve lift increases. This allows the engine to breathe better, resulting in more power. These heads also feature heart-shaped combustion chambers for faster and smoother burning of the air/fuel mixture.

Examination and Cleaning

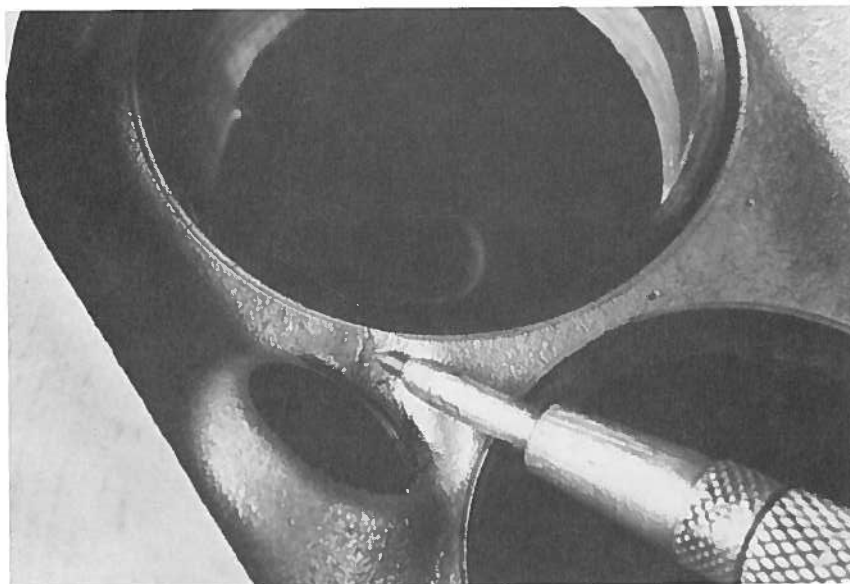
As you clean your heads, examine them closely for signs of damage or impending disaster.

Begin cleaning the heads by removing any debris that remains on the gasket sealing surfaces. This entails the use of gasket scrapers and



A rotary brush can be used to clean the combustion chambers on cast-iron heads. However, to avoid creating potential leak paths, do not use the brush on any of the head sealing surfaces.

Clean aluminum heads with a strong solvent, such as Gunk's Hydro-Seal II, a stiff-bristled nylon brush, and a nylon gasket scraper.



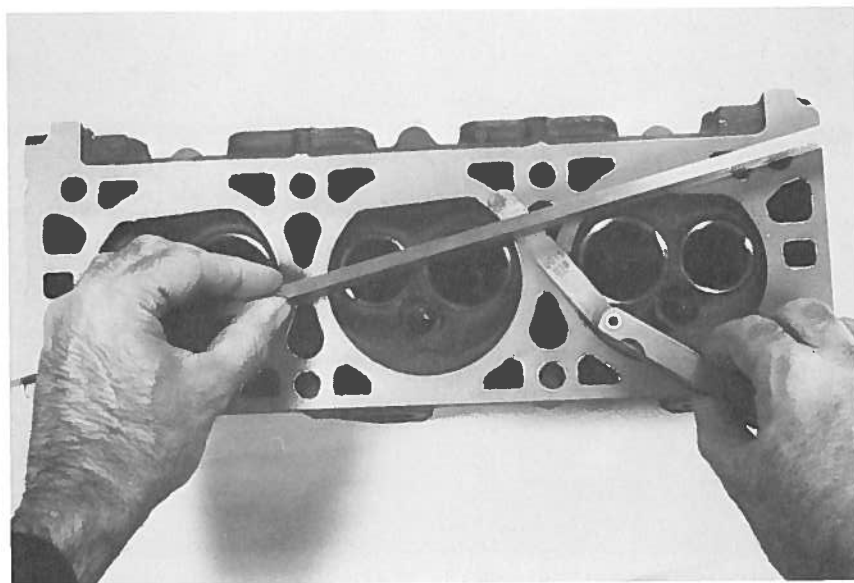
Cracks in the cylinder head indicate engine overheating. Magnaflux inspection or spray dye penetrants can help you

find these cracks. Any cylinder head that's cracked should be scrapped.

any debris that remains on their sealing surfaces. In a pinch, you could use a metal scraper, but you must first round off the corners of the steel blade, using a grinder or file. This will minimize the chances of gouging the aluminum with the corner of the blade.

After the gasket debris is removed, turn your attention to the com-

bustion chambers. To clean the combustion chambers in cast iron heads, you can use a rotary wire brush chucked into a drill motor. After the combustion chambers are free of carbon, clean them with a solvent such as lacquer thinner. This will remove any remaining carbon dust, allowing you to check the combustion chambers for cracks.



A machinist's straight edge and a set of feeler gauges can tell you whether the head is warped. Be sure to hold the narrow portion of the straight edge

against the head, and check the head in at least three places: diagonally from corner to corner (in both directions) and parallel to the length of the head.

When a cylinder head cracks, it usually happens between the intake and exhaust valve seats. This type of damage is most often due to overheating.

To verify a crack problem, check it with one of the crack detecting methods discussed earlier in this chapter. Cracked heads must be scrapped. (If either head is cracked, check the cooling system before starting your newly rebuilt engine.)

The studs on the heads on which the intake manifold mounts need not be removed for general engine rebuilding. Be thankful, because these bad boys are tough to remove. If they need to come out for any reason, have your local machine shop wrestle with them.

Checking Flatness

To safeguard against blowing a cylinder head gasket, and the resultant rebuild, you need to check the flatness of the cylinder heads. This requires a machinist's straight edge and a set of feeler gauges.

The checking process is just like the process you used to check the decks of the cylinder block in the "Checking Deck Flatness" section of this chapter. To review, hold the narrow side of the straight edge in the center of the head so that it runs from front to back. Then slip in the largest feeler gauge that will fit in between the straight edge and the head. This represents maximum cylinder head warpage. If this figure exceeds 0.003in for cast-iron heads and 0.002in for aluminum heads, the heads must be sent to a machine shop for milling.

Milling

If your heads are warped beyond specifications, they can be milled flat. But beware, since only four bolts clamp the head to each cylinder, the head doesn't have a lot of reserve clamping power. Milling the head can reduce this clamping power and, if too much material is taken off the head, the head gasket may fail. And this doesn't even address the mismatch between the inlet manifold and head that grows as more material is shaved off the head, or the fact that milling the heads causes the compression ratio to increase to a potentially destructive level. The upshot of all this is that you must impress upon your machinist that you want only the absolute minimum amount of

metal removed from the heads.

Heat Straightening

Heat straightening eliminates the need for removing metal from a warped head to straighten it. Instead, the head is placed in a fixture and measuring instruments bear against the head. The head is then heated and twisted back into shape. Since this is the latest technology, you'll really have to hunt for a machine shop that offers it.

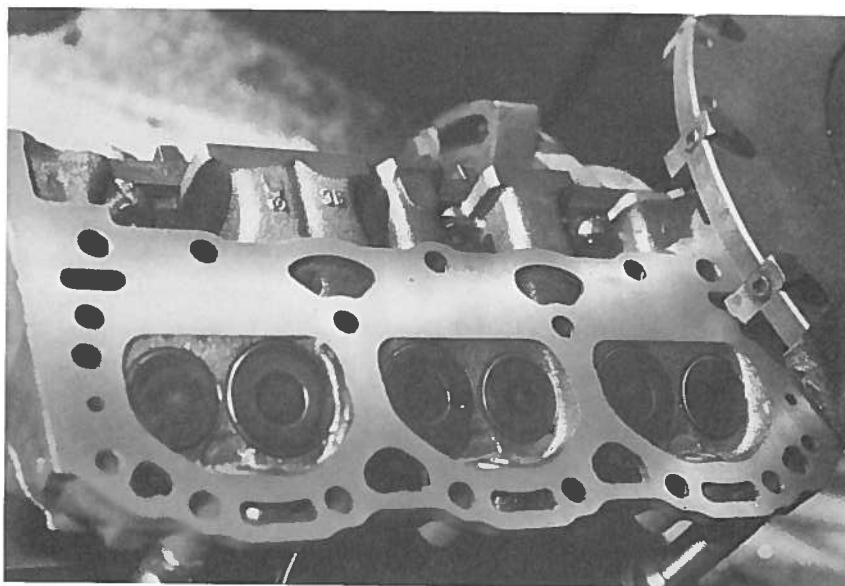
Valves

Valves seal the intake and exhaust ports, and if they're bent, improperly ground, or sticking in the guides, they can cause a number of engine problems ranging from a loss of power to spark knock. Valves have four basic parts: tip, stem, head, and face. Each of these parts needs to be of a certain caliber for proper valve operation.

One of the basic tenets of valve design is that the valve stem must be at a 90deg angle to the head so that the valve can seat fully. If the valve doesn't seat fully, compression blows past it, reducing power. Also, the entire perimeter of the head doesn't have a chance to transfer the tremendous heat it is exposed to to the valve seat and, in turn, to the coolant. This causes the valve to overheat and burn. In severe cases, part of the valve can actually be eaten away.

Another ally in this seating and heat transferring business is the fit of the valve to the valve seat. To ensure that the valve seals well, the valve seat is ground at an angle that's one degree different than the angle of the valve face. This difference in angles is referred to as an "interference fit." As the miles pass, this interference fit between the valves and the valve seats wears, and contaminants such as carbon join forces to keep the valves from seating properly, which, in turn, robs the engine of power. To renew this relationship between the valves and seats, they must both be ground.

Valves that have never been ground can usually be ground at least once. The limiting factor here is the size of the valve margin—that is, the distance from the face to the head. If this distance is less than 0.040in for intake valves and 0.060in for exhaust valves after the valve face has been ground sufficiently enough to remove imperfections, the valve must be discarded.



If your heads need to be milled, have the machinist remove as little material as possible to avoid trouble down the

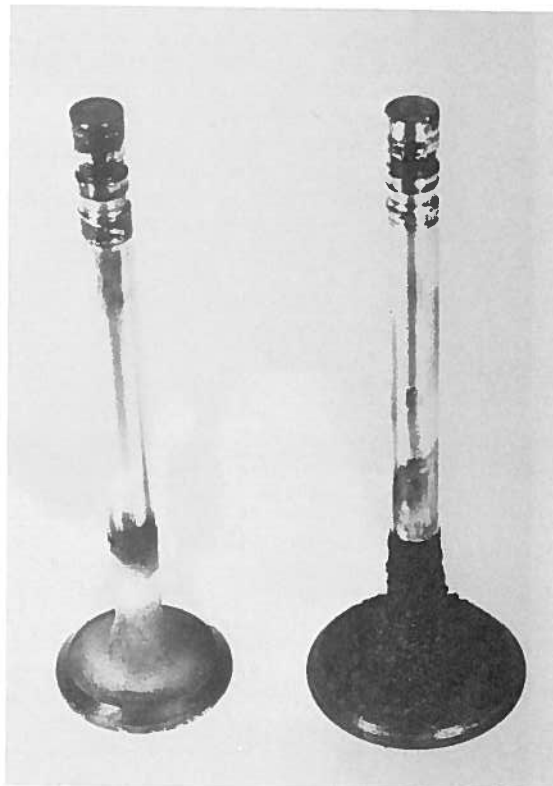
road. Heat straightening of aluminum heads is preferred to milling because no stock is removed.

Also, keep in mind that the margin is different between intake and exhaust valves due to the different temperatures to which they're exposed. Exhaust valves need a larger margin to prevent them from overheating and burning than the intake valves do.

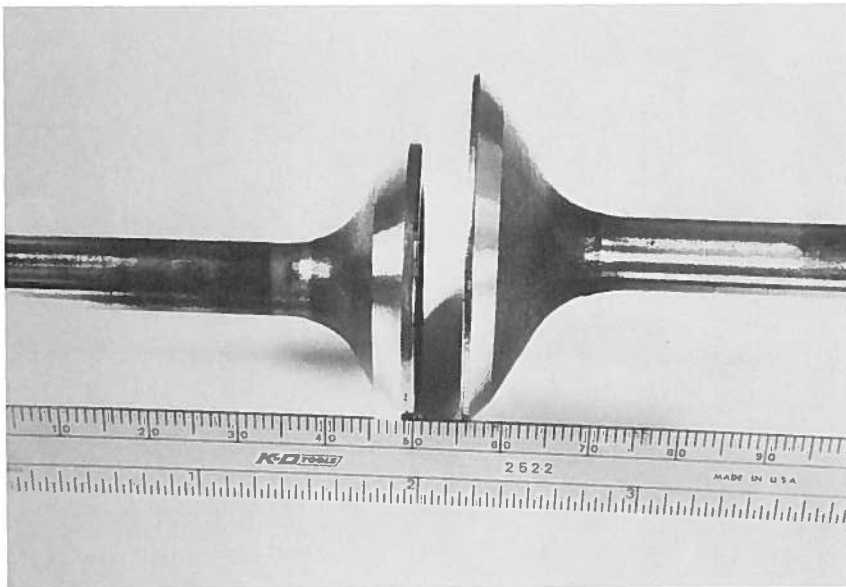
Together with the valve guide and valve stem seal(s), the condition of the valve stem is an important determinant of oil consumption. If clearance between the stem and guide is too great, excessive amounts of oil will be pulled into the combustion chamber and burned, so check the condition and size of the stem and guide.

First take a close look at the stem. It should be smooth and shiny. If it appears to have scratches on the surface, it may be due to dirt getting past the air filter into the engine or to infrequent oil changes. Deep scratches mean the valve is shot. During the rebuilding process, you also need to check the diameter of the valve stem with a micrometer in three places: the top, middle, and bottom. If it's worn beyond specifications, toss the valve out.

Proper measurement of the valve guide is important as well. To do this, you'll need a split ball gauge and a 0–1in micrometer. Since valve guides wear most at the top and bottom, this is where you should take your readings. If either reading is beyond specifications, the guide will



Since they run at a higher temperature, an exhaust valve (left) tends to gather far fewer deposits than an intake valve (right). A wire brush can be used to clean off deposits, but keep the brush away from the valve stems, as you can damage them. These valves were cleaned, ground, and reinstalled.



The edges of the exhaust and intake valves need to be of a minimum width (margin) to prevent burning. As you can see on this pair of freshly ground

valves, the margin on the exhaust valve on the left is almost twice as wide as the one on the intake valve on the right.

have to be reamed and a bronze-silicon insert installed at the machine shop. Fortunately, the valve guides in the 60deg V-6 have proven to be very durable. The engine I rebuilt to illustrate this book had more than 160,000 miles on it and the valve guides were still within factory specs!

Valve Seats

Reconditioning of the valve

seats is dependent upon the condition of the valve guides. Since the guides are used as a pilot for the seat grinding tools, they must be within specifications for diameter and trueness. If they're not, it's impossible to grind the valve seats properly.

The valve seats in the 60deg V-6 are cut on three angles, as are most production engines. Consequently, three stones cut at different angles

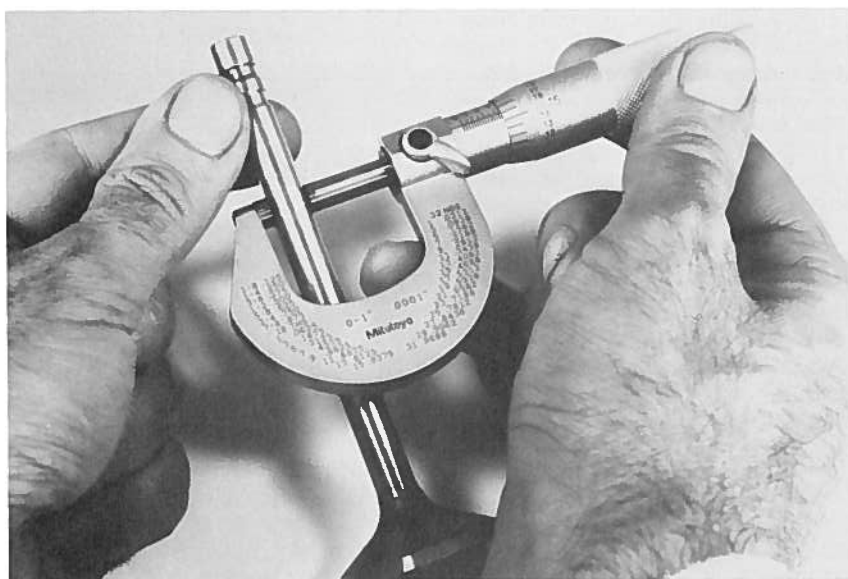
are used to machine the seats. This ensures adequate flow past the valves while retaining an interference fit for good valve sealing. This is one of the reasons that you can't properly seat the valves using lapping compound, the gritty paste that some people still use to seat valves in their seats, supposedly for that "extra edge." Funny thing is, all it really does is destroy that "edge"—called the interference fit—that is critical to valve sealing.

Squareness of the valve stem tips is important as well. If they're not square to the stem, you'll have more valvetrain noise. Most machine shops grind the tips as well as the valve, but be sure to ask.

Valve Springs

Valve springs are responsible for closing the valves. To do this, they need to have sufficient tension. Unless you have a spring tester, you can't determine whether the spring has enough tension to do its job. But if you have more than 100,000 miles on your engine, it's a good bet that the springs are ready for the wastebasket. Although you could have your springs tested at a machine shop, if they've been around for six figures they've weakened and fatigued considerably, so do yourself and your engine a favor and replace them.

Valve springs also need to be



Measure the valve stem in three places to check its diameter.



A split-ball gauge should be used to measure the top and bottom of the valve guide. Bell-mouthed guides will need to be repaired with a bronze-silicon insert.

square to the cylinder head so that they push the valves straight up. This keeps valve guide wear to a minimum. You can check the squareness of each spring with a common square. With the square and the spring on a flat surface, hold the spring against the square and rotate it. If the top of the spring moves up and down a total of more than 1/16in, the spring should be discarded.

Valve Stem Seals

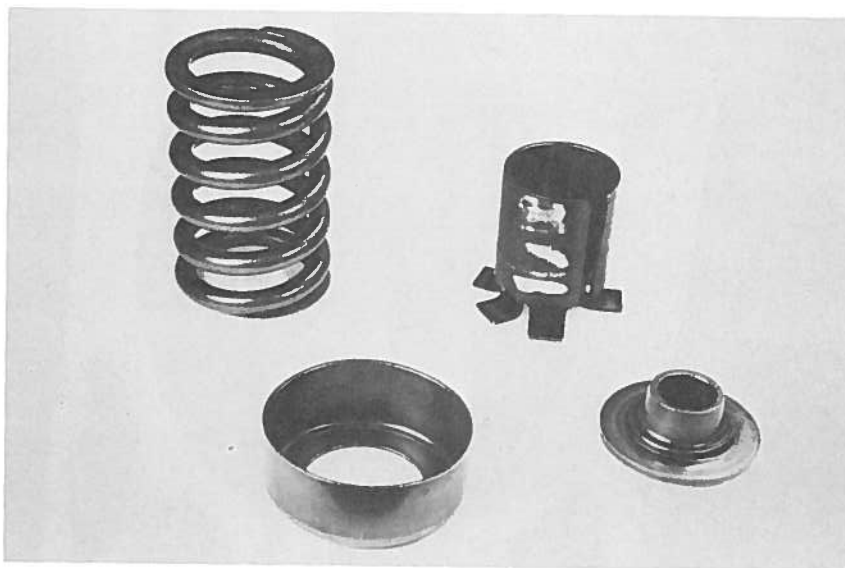
Valve stem seals are designed to control the flow of oil into the valve guide. If too little oil gets into the guide, the valve stem becomes galled or, in severe cases, stops moving altogether. On the other hand, if too much oil is allowed past the seal, it's sucked into the combustion chamber and burned. This is usually true of seals that have been subjected to intense heat for an extended period of time.

Two types of valve stem seals are used in various combinations on the 60deg V-6: O-ring (near the top of the valve stem) and guide-mounted (fitted to the top of the valve guide). Whenever you're rebuilding an engine, replace the valve stem seals, and make sure your new seals are made of Viton, a synthetic material that is extremely heat resistant. Remember, heat is the number one enemy of valve stem seals. Viton valve stem seals cost a little more, but they're well worth the price and are often included in quality gasket sets, such as those offered by Fel-Pro.

Cylinder Head Gaskets

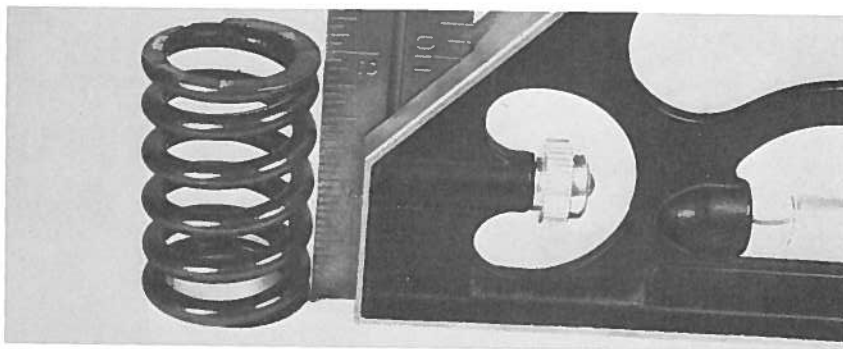
With all the expanding and contracting between the block and heads, coupled with the need to seal the cooling and lubrication systems, head gaskets have one tough job. Over the years, however, modern engineering and materials have produced head gaskets that usually last the life of the engine. So head gasket failure doesn't happen very often, but when it does, you need to find the source of the problem before you bolt the engine back together. Otherwise, it'll crop up again.

Minor cracks or indented areas in the metal shielding around the cylinder bores indicate spark knock or preignition. This can be caused by several things, including lugging the engine, using fuel that's too low in octane, using spark plugs that are too hot, an overly lean fuel/air mixture, an overheated engine, deposits on the



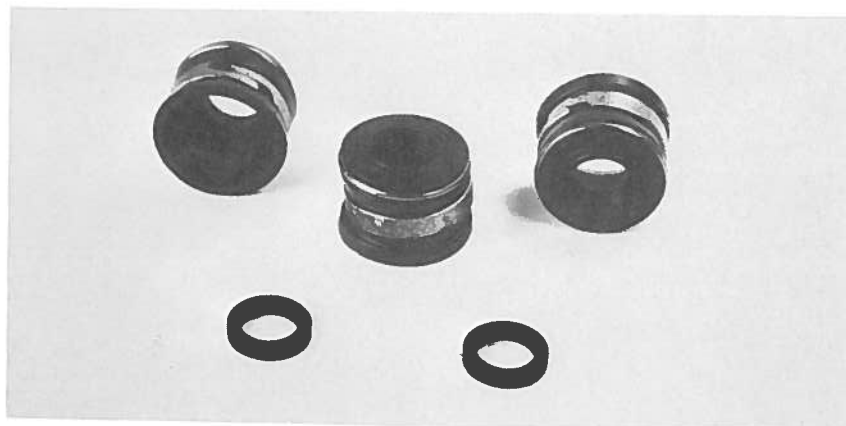
It's always a good idea to replace the valve springs when you're rebuilding an engine. The damper to the right of the spring is fitted to the inside of each

spring and helps extend its life. The oil shedder (front left) and valve stem cap (front right) rarely, if ever, need to be replaced.



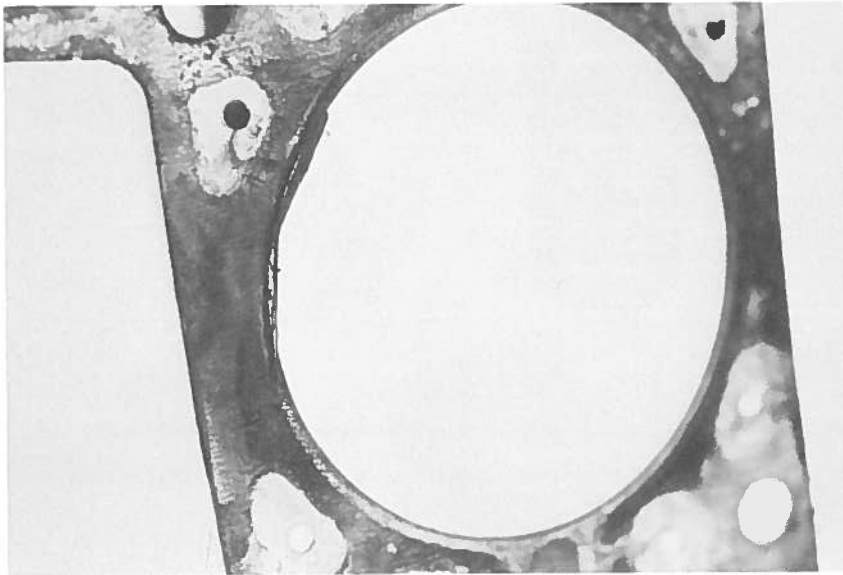
A spring that isn't square accelerates wear of both the valve guide and the valve. Check all your springs to be sure

they're within 1/16in of being square. Less is definitely better here. Rotate them next to a square to check them.



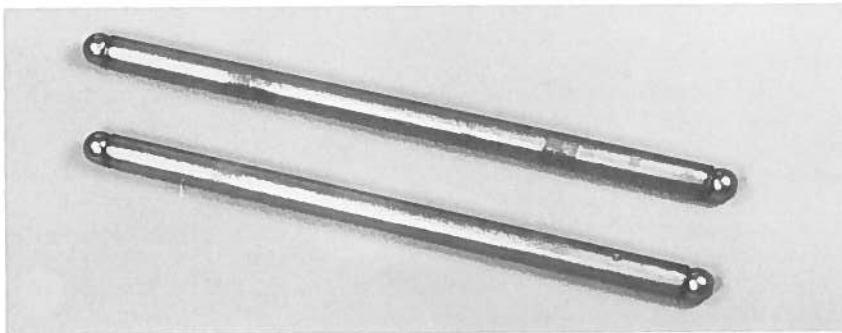
O-ring seals (foreground) have square edges and are fitted near the top of the valve stem. Guide-mounted seals

(background) control oil wherever the valve stem is positioned.



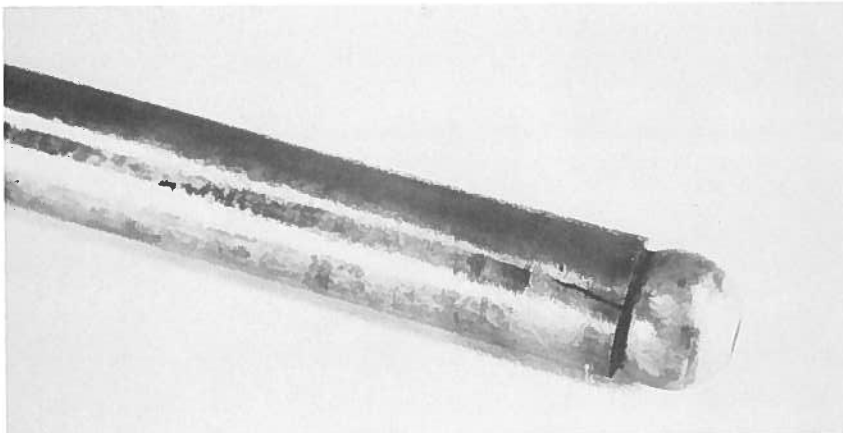
This head gasket has blown, as evidenced by the metal shielding that has torn away from the gasket and by the eroded gasket material from the nearby

coolant hole. You need to find out what caused the problem before you button your engine up, or the problem will come back to haunt you.



The pushrods for the intake valves on splayed-valve heads are shorter than those used for the exhaust valves. Also,

the pushrods for the intake valves have an orange stripe, while the exhaust pushrods are marked with a blue stripe.



After hundreds of thousands of cycles, pushrods can fatigue. They crack like

this when they've reached the end of their useful life.

cylinder head or piston crown, over-advanced ignition timing, excessive milling of the cylinder head(s), and knife-edged exhaust or intake valves. Check for these problems if a head gasket has failed.

If your engine had a problem with overheating, and the cooling system passed inspection, compare the holes in the head gaskets with those on the block. The wrong head gasket may have been used, restricting or blocking one or more of the coolant passages in the block and/or heads. If you suspect a failed head gasket, look for erosion of the gasket when you remove the cylinder heads. Eroded areas on the gasket indicate that the head bolts weren't tight (or they cracked), the head and/or block is low in that area, or the head gasket was faulty.

Pushrod Identification

If you have a 1986 or earlier engine, you'll find that the pushrods for both the intake and exhaust valves are all the same length. However, things changed in 1987 with the advent of the new Generation II aluminum heads. Because the geometry between the intake and exhaust valves was different, the pushrods for the intake and exhaust valves needed to be different lengths.

Consequently, all 1987 through 1993 2.8-liter, 3.1-liter, and 3.4-liter engines with aluminum heads have intake pushrods that are shorter in length than the exhaust pushrods. The intake pushrods can be identified by their 6in length and their orange paint markings. Exhaust pushrods are 6-3/8in long and are marked with blue paint.

Inspection

Just like the columns at the coliseum in Rome, pushrods depend upon their straightness to give them strength. When bent, they lose much of their strength. To check their straightness, roll them across a piece of plate glass. If the ends or the middle move away from the glass, the pushrod is bent and must be replaced. If a pushrod is bent, check the condition of its mating lifter, guide plate, rocker arm, and valve. A problem in one or more of these components more than likely caused the pushrod to bend.

The pushrods used with the 60deg V-6 have hardened balls welded to their ends. Look at them

closely. If the normally round and smooth ends are excessively worn, they'll be misshapen or have a rough texture. Pushrods with this type of damage should be discarded.

After awhile, pushrods may begin to fatigue. This fatigue appears as a crack beginning below the hardened ends and migrates down the tube. This type of problem cannot be repaired, so the pushrod should be replaced.

Pushrods are hollow to allow engine oil to move from the lifters to the rocker arm assemblies. Check the interior of each pushrod to ensure that no obstructions are preventing the oil from reaching the rocker arms. If this passageway is restricted, enough oil won't flow through and disaster in the form of rocker arm and valvetrain damage will follow.

To check for restrictions, look into the hole in the end of the pushrod. If it's clear, you should be able to see the light of day. If you don't, there is probably accumulated engine oil sludge inside. If soaking the pushrod in solvent doesn't clear the restriction, you may need to blow it out with compressed air. Ultimately, the passageway must be perfectly clean and clear to allow lubricating oil to reach the rocker arm and valve assembly.

Pushrod Guide Plates

The pushrod guide plates are se-

cured to the heads by the rocker arm studs. These rarely wear, and cause only a slight amount of wear on the upper end of the pushrod. So all you need to do is clean them, and remember to keep the guide plates with the valvetrain components they were originally mated with.

Rocker Arm Assemblies

The rocker arm assembly includes the nut, rocker arm, and rocker ball.

As you remove the nut from each rocker arm assembly, take note of the effort required. Each nut is designed with what is referred to as "prevailing torque," which means that the nut is supposed to resist rotation which helps prevent it from loosening. If the nut doesn't possess enough prevailing torque, it will probably loosen during engine operation. And if it loosens up far enough, the valve won't open as far as it should, causing engine performance to suffer. It may even cause rocker arm and/or valve damage. So, if one nut is noticeably easier or harder to remove than the others, it should be discarded and a new one used.

Another thing you need to keep in mind is that the rocker arm and ball for each valve wears into a specific pattern. If you try using a new rocker arm with an old ball, or an old rocker arm with a new ball, both will fail. Consequently, if you need to re-

High-Performance Tip: Rocker Arm Durability

To increase rocker arm durability, remove all signs of factory flash from the lube hole in the arm. A die grinder equipped with a small grinding stone can help you here.

place a rocker arm or ball, you must replace both the rocker arm and the ball.

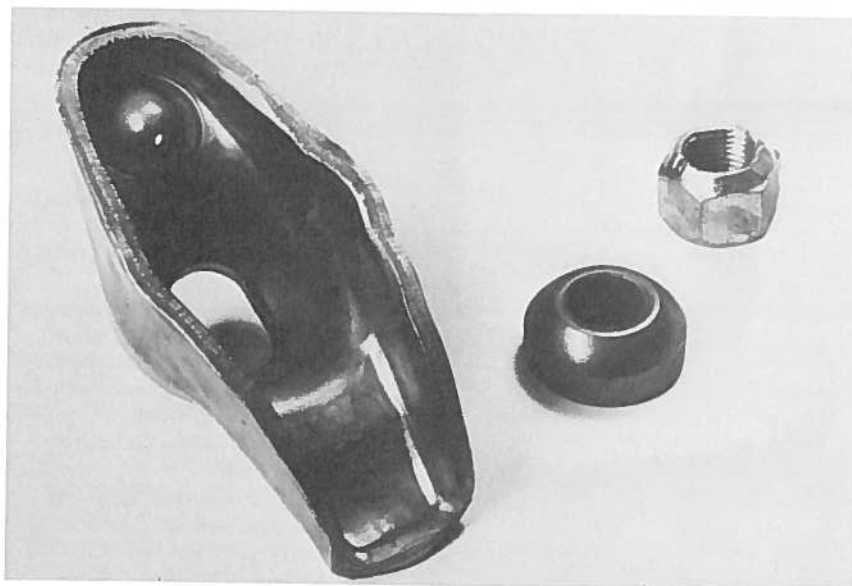
As you remove each rocker arm and ball, look closely at their mating surfaces. They should be smooth, with no signs of discoloration. If the surfaces are rough, chances are the oil wasn't changed often enough or the air filter was missing. Any rocker arms or balls that are damaged must be replaced with a new rocker arm and ball.

Water Pump

Aside from coolant dripping out of the vent, the only other check you can perform on a water pump entails wiggling the pump shaft while securely holding the pump. If the shaft moves perceptibly, the pump bearings are on the way out. If your water pump is afflicted with either of these problems, you'll need to buy a new one.

Oil Pan

To prep the oil pan, scrape all

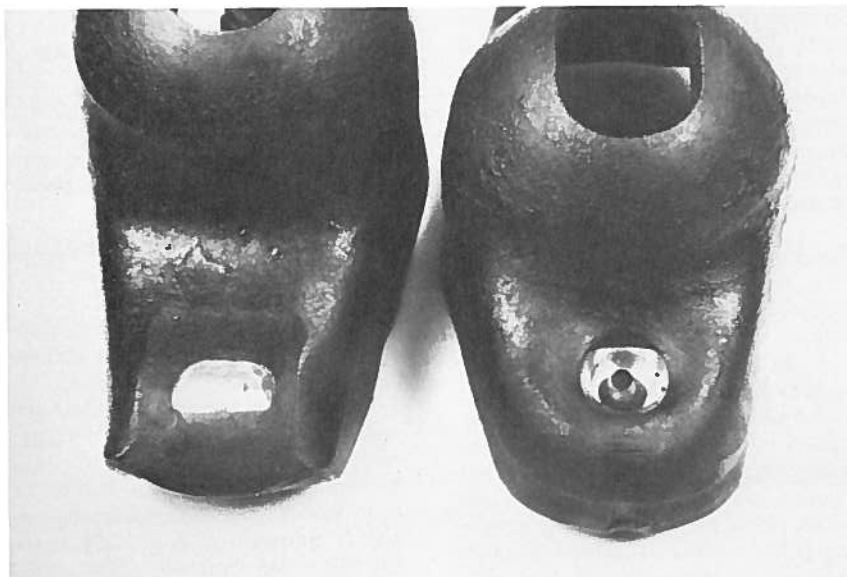


The rocker arm and ball wear together and must be kept together if they are to be reused. The nut used with each

rocker arm assembly is crimped to prevent it from backing off.



Scratches such as this on a rocker ball indicate that the oil wasn't changed as often as it should have been. If any of your engine's rocker balls look like this, they need to be replaced, along with the rocker arms to which they were mated.



If a ridge can be felt on the end of the rocker arm that contacts the valve stem tip, it should be discarded. Likewise, if

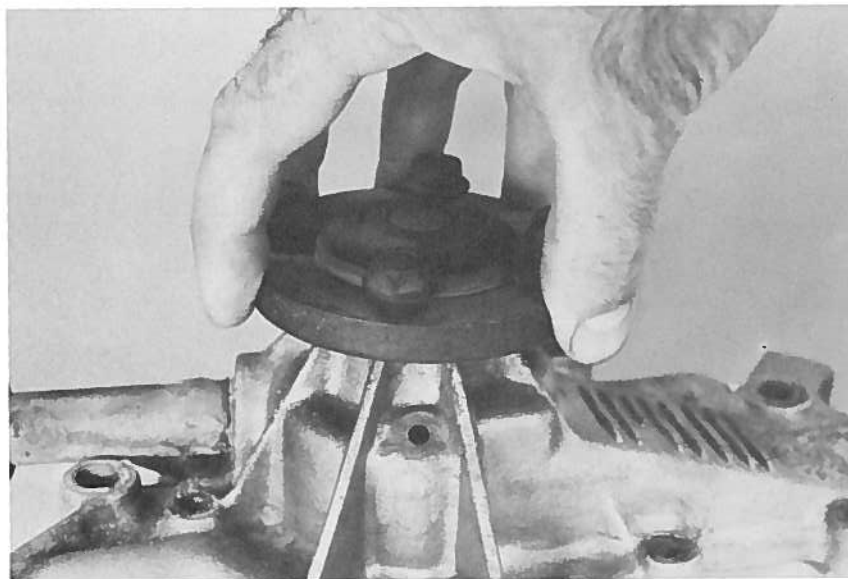
the pushrod ball seat is severely pitted, throw the rocker arm away. Look at the mating end of the pushrod as well.

the old gasket and sealer from its flanges. Clean up any remaining residue with a grey Scotch-Brite pad.

When the flanges are clean, take a close look at them. If the oil pan retaining bolts had been over-torqued, the area surrounding the bolt holes may be raised, or the flange itself may be bent. Neither of these conditions lends itself to a leakproof

seal.

Rectify this situation by supporting the damaged area over a block of metal or wood chucked into a vise. This custom "anvil" should be just wide enough to support the flange, but not so wide that it supports its edge. Use light hammer blows on the distorted areas to repair the damage.



If the water pump shaft has any looseness, the bearings are shot. Coolant dripping out of the vent hole (shown be-

low the fan mounting flange) indicates that the seal is gone. Either problem means the pump must be replaced.

Rocker Arm Covers

Quite often, rocker arm covers are subject to abuse. The bolt holes get pulled out of shape when someone over-torques the retaining bolts, or the flanges get bent if the cover is dropped. Whichever scenario best describes your situation, reverse it by using the same technique you used for the oil pan.

Sensors

After seeing a number of years of service, the business ends of sensors can become corroded. Since this can affect the sensors' ability to sense, remove all traces of corrosion with a small wire brush. Clean the electrical terminals on the sensors as well, using a wire brush or 400-grit sandpaper as needed.

Fuel Injectors

O-Ring Replacement

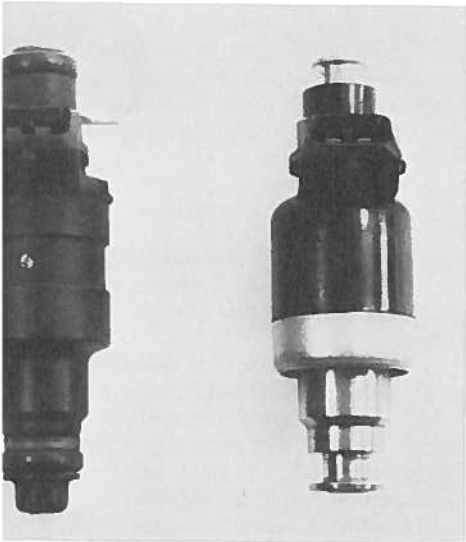
During a rebuild is a good time to replace the O-rings at the top and bottom of each fuel injector. Heat- and age-hardened O-rings don't seal well when reused, and if your engine had a problem with stalling at idle, this could be the fix it needs.

Two types of fuel injectors have been used in MPFI engines: a pintle-type for earlier designs and Multec fuel injectors on later engines.

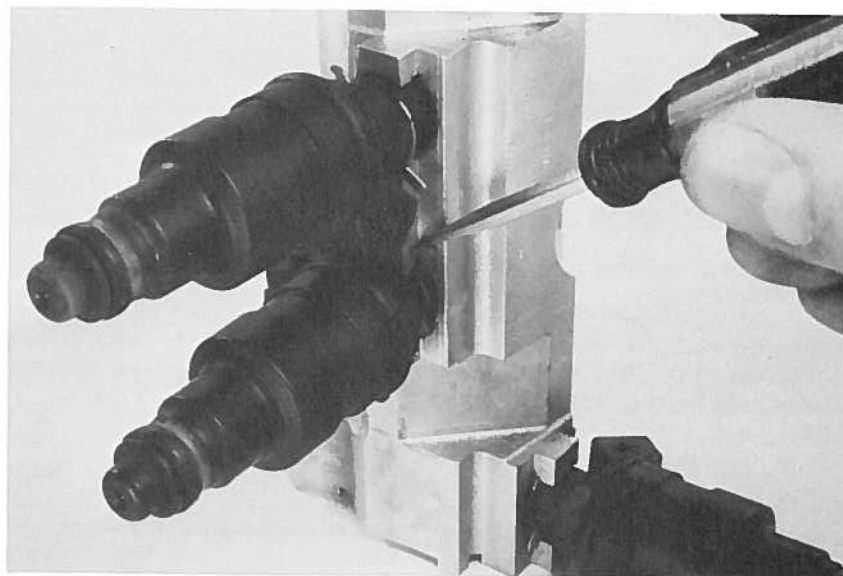
Each injector is secured to the fuel rail with a metal locking ring. To facilitate injector installation and removal, the ring is shaped like a "C" with a tab on it. To remove an injector, rotate the tab on the ring so that the open section of the ring aligns with the raised section of the fuel rail. This effectively "unlocks" the injector from the rail. Then rock the injector side-to-side while pulling it out of the rail.

Remove the O-rings by cutting them with an X-acto knife. Take care not to cut or nick the injector. Replacement pintle-type O-rings come with a conical installation tool, which not only simplifies installation but also helps prevent damage to the seal from the injector ends. Simply slip the cone over the end of the injector, lube the O-ring and tool with engine oil, then slide the O-ring over the tool onto the injector; just make sure the O-ring isn't twisted. Multec injectors require only that you oil up the O-rings and roll them into position.

When you've installed the new O-rings, install the injectors into the fuel rail by lubricating the O-rings



The pintle-style injector on the left was used on early engines. Self-cleaning Multec injectors (shown on the right) are used on later engines.



A metal ring locks each injector into the fuel rail. Unlock the injector by rotating the ring with a small screwdriver until its

open end faces the rib on the fuel rail. Then pull the injector out.

with engine oil and then pushing the injectors into the rail, with their electrical connectors facing out. They don't need to be fitted to any particular cylinder. Just make sure each retaining ring is "unlocked." Next push each injector far enough into the fuel rail so that you can lock it with the retaining ring. If you can't push an injector into the rail, the O-ring is probably hanging up on it. Pull it out and try again. If necessary, rock the injector side-to-side slightly while pushing it in so that you can "lock" the ring.

Service of these injectors is limited to replacement of the O-rings. Don't soak the injectors in any kind of cleaning solution, as it may damage the coils inside the injectors.

Intake Manifold

The primary job of the intake manifold is to distribute the air/fuel mixture to each cylinder (just air in MPFI systems). To do this, its internal passages must be free of obstructions such as casting flash and carbon. Take a careful look in each runner for obstructions. Casting flash can be removed with a file or die grinder. Large carbon deposits typically accumulate in the exhaust passage crossover in the manifold due to the extra heat generated by the exhaust gasses.

The sealing surfaces of the manifold are also important, as they prevent vacuum, coolant, and engine oil

leaks. Dress any shallow gouges by moving a file along the length of the sealing surface. Working in the direction of the sealing surface's length helps minimize the chances of a leak. Repair deep gouges with JB Weld as described in the "Epoxy-Based Adhesives" section earlier in this chapter.

Exhaust Manifolds

To prevent an exhaust leak, the sealing surfaces of both manifolds must be absolutely flat. Dress any imperfections with a fine-toothed file, making sure to work the entire surface of the port so that it remains flat. Cracks in cast-iron exhaust manifolds can sometimes be repaired using a special welding process that preheats the manifold to a specific temperature and uses a special rod for welding. Cracks in tubular manifolds can usually be repaired with MIG or TIG welding.

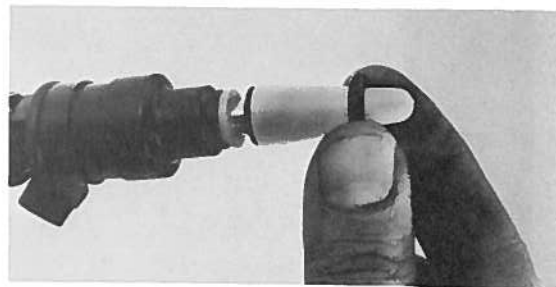
Clutch Assembly

Engines and clutch assemblies both last a long time, but if the engine is due for an overhaul, the clutch probably is, too. This is a very good idea when you consider what you had to go through to remove the engine. Consider that when the clutch goes bad, you'll have to do it all over again.

Flywheel

Flywheels are pretty durable chunks of metal. Usually, only three

things can go wrong: the ring gear teeth are chewed up as the result of a bad starter, the clutch disc surface can become warped or glazed due to a clutch (or driver) problem, or the flywheel can become heat-checked due to a slipping clutch. Your local machine shop can check for these problems and recondition most flywheels. However, if the surface of the flywheel is heat-checked, and the cracks radiate from the friction surface of the flywheel into the crankshaft flange mounting area, the flywheel must be replaced. Otherwise, it can disintegrate as you're taching out the engine—and this makes for one hell of a 35lb hand grenade!



A conical tool aids in installation of the lower O-ring on pintle-type injectors. Simply slip the cone over the end of the injector, lube the O-ring and tool with engine oil, then slide the O-ring over the tool onto the injector. With Multec injectors, just oil up the O-rings and roll them into position.

Assembly

General Information Cleanliness

You've invested considerable time in meticulously cleaning and reconditioning the engine components. Assembling the engine takes the same kind of care. If you become impatient as assembly progresses, stop! If you rush the assembly, you'll probably make a mistake; and if your mistake is significant enough, you'll have to pull the engine out to repair it. If you don't think you have time to do the job correctly *now*, do you really think you'll have time to redo it *later*?

Nor can you allow the parts to become dirty. Most engine components have carefully machined surfaces that operate within tolerances not much larger than the thickness of a human hair. If dirt is allowed to get between these components, for whatever reason, they will die a premature death,

so they must be properly lubricated, handled, and stored.

Lay cleaned parts on newspaper. Any particles that the parts do pick up from the paper are easily tolerated inside the engine.

Lubricants

Basically speaking, three different types of lubricants are used during the assembly process: engine oil, assembly lube, and moly-bdenum disulphide (moly)-lube. Each of these lubricants has certain traits that makes it right for specific uses.

If assembly lube is called for, don't use engine oil because most commercial assembly lubes, including GM's Engine Oil Supplement (EOS), have high concentrations of zinc dithiophosphate (ZDP). This additive provides protection for parts working under extreme pressure, such as bearings, camshaft lobes, and lifter

feet. If engine oil is substituted, it will be pushed out from between these surfaces, allowing metal-to-metal contact.

Assembly lube is also good for engines that will be stored for a long period of time because it is quite thick and tenaciously clings to metal. This helps prevent a dry start when the time comes to start the engine.

Assembly lubes usually come with a complete rebuilding kit, but if yours lacks it you can purchase it at most auto parts stores or speed shops. Buy only high-quality, brand-name products—and don't forget about General Motor's EOS (part #1052367). EOS is available in the parts department at practically any GM dealership and is a good choice for an assembly lube. Buy at least one quart so you can add it to the crankcase in place of one quart of engine oil. This will significantly add to the protection of the internal engine components during break-in.

Moly-lubes are another type of extreme pressure lubricant, but they offer even more protection against metal-to-metal contact than assembly lubes. Moly-lube is strongly recommended for areas of extreme pressure, such as cam lobes and lifter feet. The disadvantage of moly-lube is that it can plug an oil filter within 20–30min after the engine has started. This is one of the reasons why the oil filter should be changed after the first 30min of engine operation. Moly-lube is available at most auto parts stores and speed shops.

Whatever you do, don't use lithium grease (also known as white grease) on camshaft bearings or any other engine component. Lithium grease tends to pack into the lubrication holes of the bearing during assembly. If the grease blocks the lube holes, it won't be forced out until the engine cranks upwards of fifty times or more. In the meantime, the bearings are wearing without the benefit of oil. Definitely a bad thing. Especially in light of the fact that the first time an engine is started after being rebuilt is the most important time in



Using the right type of lubricant is critical during the assembly process. A couple quarts of GM Engine Oil Supplement (EOS) is great to have on hand and can be purchased at any GM deal-

ership. Assembly lubes and moly-lube can be purchased at auto parts stores and speed shops. Buy only name-brand products and stay away from products with unbelievable claims.